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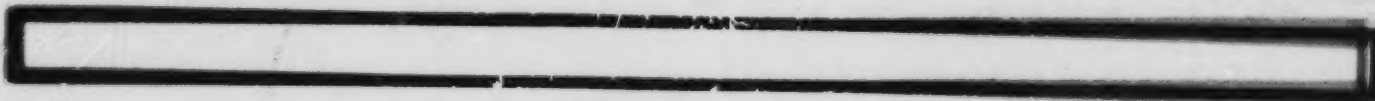
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Wisconsin Power Plant Impact Study

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DOCUMENTATION OF THE DATA BASE
Wisconsin Power Plant Impact Study

by

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This study was conducted in cooperation with

Water Resources Center,
Wisconsin Power and Light Company,
Madison Gas and Electric Company,
Wisconsin Public Service Corporation,
and Wisconsin Department of Natural Resources ✓

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FOREWORD

The U.S. Environmental Protection Agency (EPA) was established to coordinate our country's efforts toward improving and defending the quality of the environment. These efforts depend greatly on research to monitor environmental change and to determine health standards.

One project the EPA is supporting through its Environmental Research Laboratory in Duluth, Minnesota, is the study "The Impacts of Coal-Fired Power Plants on the Environment." The Columbia Generating Station, a coal-fired power plant near Portage, Wisconsin, has been the focus of all field observations. This interdisciplinary study is conducted by the Environmental Monitoring and Data Acquisition Group of the Institute for Environmental Studies at the University of Wisconsin-Madison and involves investigators from many departments at that same university. Several utilities and state agencies also are cooperating in the study: Water Resources Center, Wisconsin Power and Light Company, Madison Gas and Electric Company, Wisconsin Public Service Corporation, and Wisconsin Department of Natural Resources.

The data collected at the Columbia Generating Station by investigators at the University of Wisconsin-Madison from 1971 to 1978 are described in this volume. Each section describes a data set for each subproject. A summary or brief statement of methods, access procedures, data samples, quality assurance report, supporting documents, and qualifications of the investigators are presented.

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ABSTRACT

This volume describes the data base of the first phase of the Wisconsin power plant impact study. Data were collected by investigators at the University of Wisconsin-Madison from 1971 to 1978 during their study of the Columbia Generating Station near Portage, Wis. This volume serves as a communication link within the Wisconsin power plant impact study and as a means of making these data available to outside users for further analysis and synthesis. This volume provides a brief description of the data sets; a more extensive documentation of these sets are being published by the U.S. Environmental Protection Agency. The number accompanying each data set is unique and serves to identify a data set within the data base.

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SECTION 1

INTRODUCTION

This volume describes the data collected by investigators at the University of Wisconsin-Madison from 1971 to 1978 during a study of the Columbia Generating Station near Portage, Wisconsin. Each section describes a data set for each subproject. The information presented includes a summary or brief statement of methods, access procedure, data samples, quality assurance report, supporting documents, and qualifications of the investigators. Related data sets collected by the Wisconsin Power and Light Company, or their contractors, also are included. Mathematical models developed or applied as part of the study will be documented in separate reports.

THE SITE OF THE COLUMBIA GENERATING STATION

The Columbia Generating Station is a two-unit, 1,054-MW coal-fired electrical generating station located on the eastern floodplain of the Wisconsin River, approximately 6.4 km south of Portage, Wisconsin (Figure 1). The facility and adjacent land are owned and operated by a consortium of three utilities: Wisconsin Power and Light Company, Wisconsin Public Service Corporation, and Madison Gas and Electric Company. Columbia I, which went on-line for commercial operation in May 1975, generates 527 MW. Columbia II, a second unit of similar size, began operation in April 1978.

The Columbia Generating Station was constructed on a 1,900-ha wetland site--owned by the Wisconsin Power and Light Company--located in the towns of Dekorra and Pacific, Columbia County, Wisconsin (Figure 2). The land comprising this site is bounded on the south by County Trunk Highway J and Rocky Run Creek; on the east by the Madison Branch of the Chicago, Milwaukee, St. Paul and Pacific Railroad; and on the north by the north section line of Sections 21 and 22, Town of Pacific, T12N., R9E. The plant site is located in south central Wisconsin, approximately 50 km north of Madison, Wisconsin.

Of the total 1,900 ha that make up the site, 445.5 ha have been permanently altered by the installation which includes a 202.5-ha diked cooling lake, 28.4 ha ash basin, coal storage area, coal train tracks, coal handling facilities, boiler and turbine-generator building, parking lot, and access roads. The remainder of the site--that portion immediately adjacent to the Wisconsin River and its tributary, Duck Creek--has been set aside from station development because of environmental considerations.



Figure 1. Location of the Columbia Generating Station in Wisconsin.

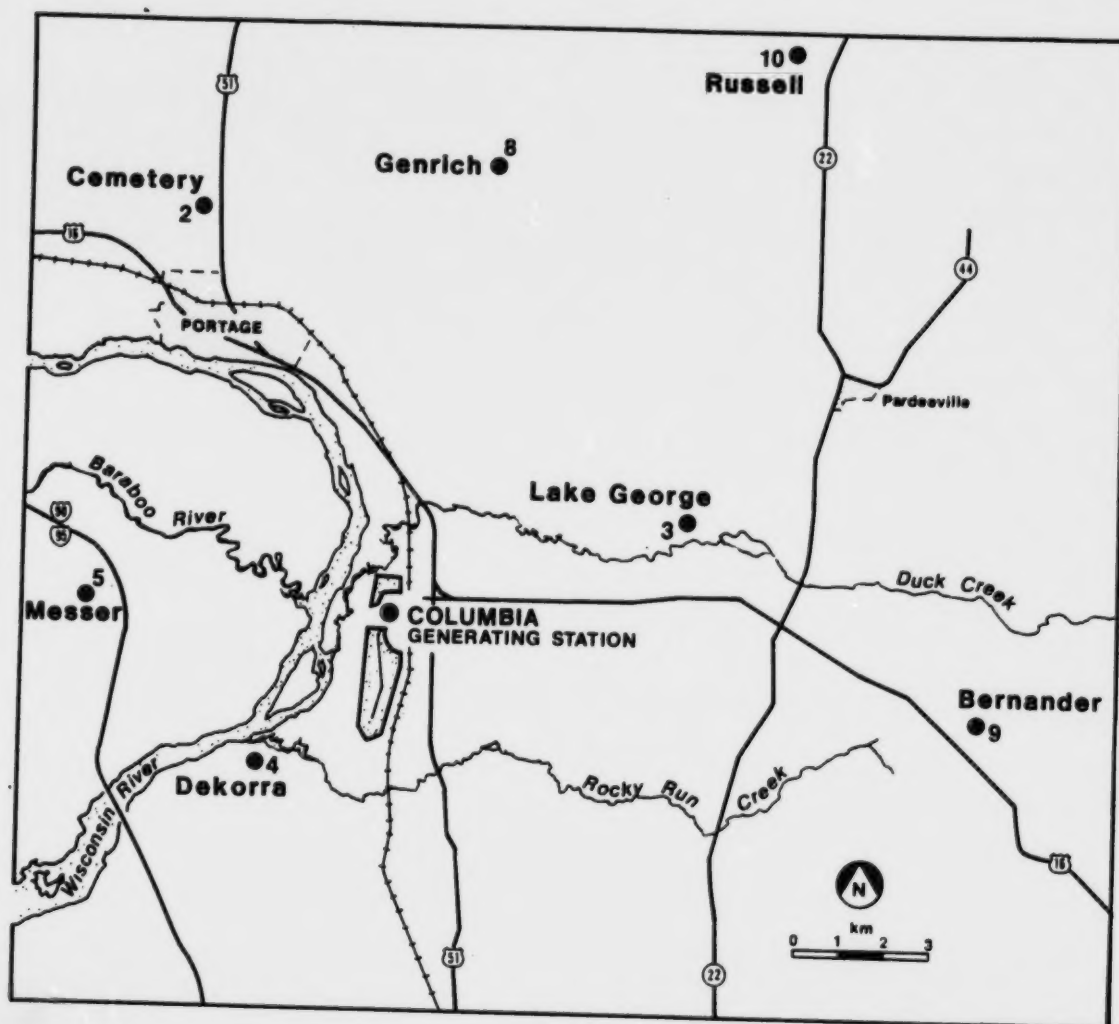


Figure 2. Location of SO₂ monitoring sites in the vicinity of the Columbia Generating Station.

The natural ground at the Columbia Generating Station site ranges in elevation from 237 to 248 m above mean sea level (MSL). The higher areas are well-drained since the underlying soil is fine to medium sand. The elevation of most of the site, however, is < 239 m and these low areas usually are wet throughout the year because of groundwater discharge.

The geology beneath the site of the Columbia Generating Station consists of irregularly eroded Upper Cambrian quartz sandstone overlain by sediments from glacial lake bottoms and drift deposits of the Green Bay lobe of the Wisconsin ice sheet. The bedrock is composed of Upper Cambrian sandstones and Pre-Cambrian granites which occur 125 m below the surface. Sandstone has been deposited upon the basement rock and varies in thickness from about 107 to 12.2 m. Near the surface the sandstone is minimally cemented and, therefore, more nearly resembles dense sand. This material often is referred to as "weathered sandstone." The surface is covered by a layer of peat 1.5 m thick, which overlies a thin layer of clay and silt containing organic matter (between 15.2 and 30.4 m thick).

The site of the Columbia Generating Station is located in a groundwater discharge zone of a regional groundwater system that extends about 32.2 km to the southwest. The discharge area includes the wetlands on the site of the power plant; the wetlands to the east of the site, which are used for mint farming; and extensive wetlands along the lower reaches of Rocky Run Creek. The marsh on which the site is located occupies a former river channel. A well-developed groundwater flow system exists in the Cambrian sandstone.

The low areas also receive groundwater recharge from the upland areas that are located on the site and adjacent to the site. These upland areas act as recharge areas during precipitation when the infiltrating water flows toward the low areas. Travel time for water from the upland areas to the low areas is usually < 3 months and, therefore, flow rates are seasonally variable. Prior to construction of the cooling lake, approximately 50% of the groundwater discharging to the low areas during the spring originated from the upland areas on and near the site; during the summer it dropped to < 5%.

Of the 1,900 ha of land acquired for the Columbia Generating Station site, approximately 65% is classified as "lowlands"--a flat floodplain formed on peat-bog wetland overlying sandy fluvial deposits, ice contact till, or dune sands. The remaining "uplands"--occasional oak covered hills in the southern portion of the site--have topsoil consisting of fine sand, gravel, and various-sized boulders.

The site covers a range of plant and animal communities, including aquatic sedge-meadow wetland, wet forest, and dry forest areas. The terrain in the vicinity of the site is flat except for the west-southwestern sector where the eastern edge of the Baraboo Hills range approaches to within 6.4 km of the stack. The Baraboo range consists of wooded, rolling hills which rise 182.8 m above the base of the stack of Unit I. The rest of the land around the generating station is farmland with occasional woodlots and extensive wetlands.

The two-unit power plant is located on one of the upland hills. Several other hills were removed completely for construction material. Dikes for the ash pit and cooling lake were constructed on the wetland.

The station proper floor elevation is 246.2 m above MSL, placing the station at about 4.3 m above the maximum flood of record and 5.5 m above the normal high water level of the Wisconsin River.

POPULATION

The power plant was built in a relatively unpopulated area. The population for all towns within 16 km of the Columbia Generating Station is shown in Table 1.

TABLE 1. POPULATION OF TOWNS IN THE VICINITY OF THE COLUMBIA GENERATING STATION

Columbia County	Population 1970 census ^a	Estimated 1980 population
Arlington Town	701	840
Arlington Village	379	400
Dekorra Town	1,763	2,100
Fort Winnebago	673	740
Lowville Town	819	900
Marcellon Town	759	835
Pacific Town	756	830
Pardeeville Village	1,507	1,660
Portage City	7,821	8,600
Poynette Village	1,118	1,230
Rio Village	792	870
Wyocene Town	1,098	1,210
Wyocene Village	890	980
Total	18,995	21,105

^aSource of data is 1970 U.S. Census Population.

The service area for the three utility companies that built the Columbia Generating Station includes the area of Wisconsin from the Illinois border to the Michigan border in the northeast region of the state. The total size of this service area for the three utilities encompasses approximately 40% of the total land area of Wisconsin.

The major generating plants owned by the three utilities are interconnected by a transmission-system network that includes a series of 115/138-kV transmission lines. In addition, all three utilities have an extensive network of 69-kV transmission lines. In several instances, these

high voltage transmission lines are interconnected with high-voltage transmission lines from other utilities in the state which--in turn--reinforce the grid system of electrical energy in Wisconsin.

The present town population density (number of people per square mile) is highest in the towns of Pacific and Dekorra, in the immediate area of the plant site, and in Dane County which is to the south of the plant site. The city of Portage, 6.4 km north of the site, is the largest nearby city. Portage has a population of approximately 7,800 people, but the predominantly rural area north and northeast of the plant has the lowest concentrations of people per square mile found in the surrounding area. Generally speaking, those towns located east of the power plant and along the Wisconsin River from Portage southward have relatively high population densities in comparison to the remaining sectors in the area surrounding the generating station.

Major urban areas in the vicinity of the Columbia Generating Station include Portage, Columbus, Wisconsin Dells and Lake Delton in Columbia County and Baraboo and Prairie du Sac-Sauk City in Sauk County.

The region around the Columbia Generating Station consists of rich agricultural land producing varied crops. Six of these crops are considered especially important in terms of potential environmental impact. The six crops are alfalfa, oats, soybeans, barley, rye, and wheat. All towns in the surrounding area have farms producing at least two of the above crops.

Plant Description and Operation

Construction of the Columbia Generating Station began in 1971 and was completed in 1978 (Figure 3). In April 1971 construction of the west dike began. In October 1972 the main building framework of Unit I was topped off. Stack construction for Unit I began about the same time and was finished in December 1974. In September 1973, construction of the settling basin-ashpit and dredging of the drainage-ditch were started. In January 1974 the intake channel to bring water from the Wisconsin River to the lake was begun and on 1 April 1974 the cooling lake was completed. Filling the cooling lake began 4 November 1974 and was completed by March 1975. The transmission line right-of-way was begun in July 1974. On 14 October 1974 the first coal was received. The cooling lake leaked badly so it was drained and the bottom and sides were sprayed with a bentonite sealer. The cooling lake was refilled in January 1975. The boiler superheater and reheater hydro test were conducted on 15 July 1974. The boiler boilout was conducted on 26 December 1974 and steam-to-turbine testing began during the week of 10 March 1975. On 12 May 1975, Columbia I went on-line for commercial operation. Construction of the main building of Unit II began on 9 August 1975. Foundations for the two cooling towers were laid in November 1976. The stack and the main building of Unit II were laid in November 1976 and completed in October 1977. The two cooling towers, which will be used from April to October each year, were completed in April 1978 the same month that Unit II was completed. Steam-to-turbine testing for Unit II began on 28 January 1978. Unit II went on-line at full capacity for commercial operation on 30 April 1978.

Columbia Unit I, completed in 1975, generates 527 MW, as does Unit II which was completed in 1978. Unit II was built adjacent and contiguous to the north side of Unit I. Each unit occupies an area of approximately 0.5 ha.

Columbia Unit II nearly duplicates the first unit and doubles the generating capacity of the station. The principal alterations for the construction of Unit II consisted of an extension to the main plant building, the addition of a new 198-m stack located west of the new unit, two electrostatic precipitators, and two cooling towers (Figure 3).

All coal is delivered to the station by railcars. Railroad tracks for receiving the coal were constructed parallel to, and on the west side of, the existing Milwaukee Road Railroad main tracks. Related to the coal delivery, a coal thawing shed and car dumper shed were constructed, as well as a sample house, junction house, and crusher house, all equipped with bag-type dust collectors.

Low sulfur sub-bituminous western coal is the fuel source for both units. Coal is transported to the Columbia Generating Station by unit trains from a mine located in Rosebud County, Montana (Colstrip coal). Units I and II burn approximately 302 tons/hr, or about 1.9 million tons/yr.

To comply with the air emission standards, the Wisconsin Power and Light Company purchases 1-1.2 million tons of low-sulfur coal annually from the Belle Ayr mine to mix with the Colstrip coal. This low-sulfur coal is mixed with the Colstrip coal to meet the emission standard of 1.2 lb SO₂/million BTU. The approximate proportions are 65% Colstrip coal to 35% lower sulfur coal.

From the coal handling and storage area east of the cooling lake, coal enters the plant where it is burned to make super-heated steam which drives a turbine generator in each unit. No. 2 oil is used for ignition and warm up. Columbia Units I and II each utilize a conventional pulverized coal-fired boiler with high-efficiency precipitators to remove the particulate fly ash and an overfire air system. By divesting a portion of the excess air through overfire air nozzles located above the coal burners, the formation of nitrogen oxides in the flame are reduced.

Most coal handling facilities constructed for Unit I are shared with Unit II. The coal conveying equipment was extended to Unit II. Six additional silos, as well as pulverisers, feeders, and auxiliary equipment were added for Unit II.

The high energy hot-side electrostatic precipitators installed to reduce particulate emissions collect approximately 98% of the "fly ash" residue and discharge it as a slurry with water from the cooling lake to the ashpit adjacent to the plant. The cooling lake and the ashpit were built by constructing dikes 5 m high from local silty sand on sedge meadow, a wetland plant community that builds a deep, peaty soil and is maintained by ground-water discharge.

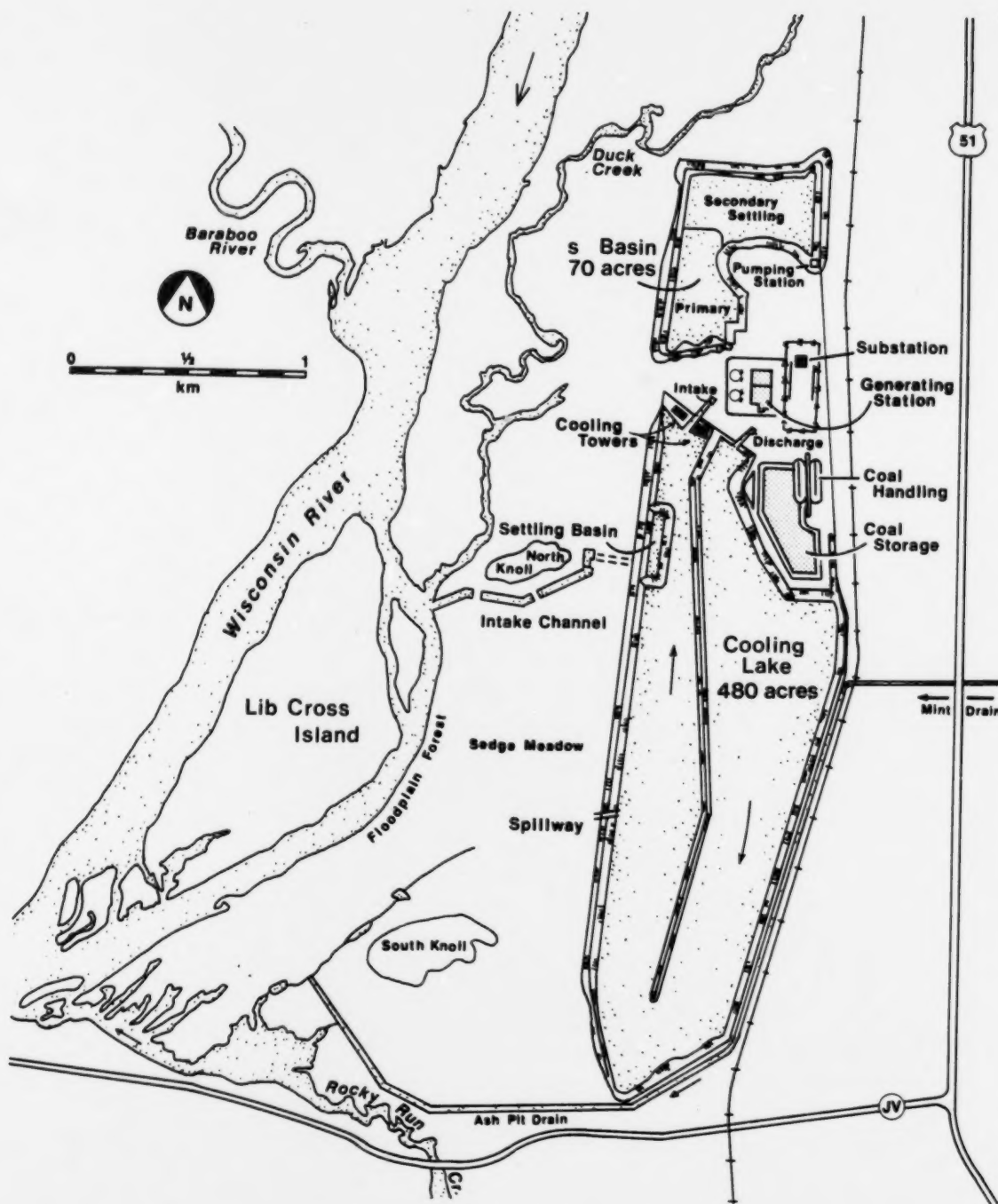


Figure 3. The study site of the Columbia Generating Station.

Ash is washed and trucked from the ash hoppers (using some water from the cooling water flow) and enters the ash basin as a slurry. Water entering the ash basin flows through a series of lagoons where the ash particles settle; the water is pumped to the ashpit drain and eventually combines with the water of Rocky Run Creek. In January 1977, Na_2CO_3 was routinely added to the pulverized coal to increase efficiency of the electrostatic precipitators. This resulted in increased conductivity and pH in the ashpit drain and Rocky Run Creek.

The chemistry of the ashpit is complex. The metal oxides that compose the major reactive portions of the ash result in a water pH of 10 to 11. Since Wisconsin water quality standards prohibit the release of water at a pH > 8, H_2SO_4 is added before the ash effluent is discharged. The addition of acid causes elements such as Ba, Al, and Cr to precipitate, forming a floc that coats the bottom of the ashpit drain and is carried with the current into Rocky Run Creek and the Wisconsin River.

Fly ash and bottom ash produced during the operation of Columbia I are pumped into the ashpit. With Columbia II in operation, the only addition to the total volume of ash is bottom ash; all fly ash from Columbia II must be disposed of dry. The ashpit structure was altered in preparation for the handling of dry ash. The ashpit will continue to receive demineralizer and blowdown waste.

Removing the bottom ash and the precipitation fly ash from the plant operation requires approximately 1,000 galls/min of cooling lake water on a daily basis. This water is pumped from the lake to hydraulically convey the particulate material in slurry form to the ash basin.

This conventional disposal method allows a substantial time for particulate matter to settle to the basin bottom. The settled ash disperses across the basin and, due to its inherent physical properties, forms a layer that makes an impervious seal and renders the bottom and inside dike perimeters nearly watertight. Even with the time allowed for settling, the water in the ash basin retains most of the soluble constituents of the original fly ash. This effluent is pumped to a discharge ditch which empties into Rocky Run Creek near the point where it joins the Wisconsin River.

Two sources provide water for plant requirements: (1) the Wisconsin River--through the intake channel, cooling lake, and screen house; and (2) deep water wells.

The systems which use river water are: (1) the condensor cooling system, (2) the ash sluicing system, and (3) the service water system for plant equipment.

Well water is used by (1) the boiler feed water system, (2) the sanitary and sewage treatment system, and (3) miscellaneous plant uses.

The cooling water from the Wisconsin River is pumped into a 200-ha, man-made cooling lake. The lake was designed to dissipate the waste heat

discharged from the plant after steam has been used to generate electricity. The total river flow removed by the intake water at the Columbia Generating Station averages 0.30% with a maximum of 1.08%. The 200-ha lake has an effective length of 5,500 m.

Water is pumped into the cooling lake from the Wisconsin River at an average rate of 50,000 m³/day. Of this water 20% is discharged to the ashpit, 40% is lost by groundwater seepage, and 40% is lost by evaporation.

Hot water is discharged at a rate of 1×10^6 m³ at the north end of the lake east of the central divide. Water circulates in a clockwise direction and is withdrawn from the north end of the lake west of the central divide. Average retention time of water in the lake is 5 days. Temperatures at the discharge point average 10 to 15°C warmer than temperatures at the intake, and decrease exponentially with distance from the discharge point. The average annual range of lake temperature is 0 to 45°C. Temperatures in the lake vary only slightly with depth. Since the water is only about 3 m deep, vertical mixing is fairly rapid.

Cooling towers were built to dissipate some of the additional waste heat generated by the second unit. The two mechanical, wet-draft cooling towers were constructed along the northern edge of the cooling lake, one tower on each side of the water intake channel. Each tower occupies an area of about 0.4 ha. Together, the cooling towers reject a heat load of 2.38×10^9 BTU's/hr in full operation.

The cooling towers are designed to dissipate the heat load of Unit II with a circulating water flow of 185,000 galls/min or 11,100,000 galls/hr, at a temperature difference of 2.38°C. The cooling towers normally operate with a temperature difference of < 3.36°C.

Each tower is 73 m long and 24.4 m wide. They rise to a height of 12.3 m at the fan deck. Each tower is composed of seven cells and each cell is fitted with an exhaust, or fan stack, rising 6.1 m above the fan deck. This gives the tower a total approximated height of 18.4 m.

The cooling towers receive warm water from the plant cooling water discharge channel. They discharge the cooled water into the plant intake channel leading to the screen house.

One water discharge outfall is necessary from each tower and the cooling water intake channel has been altered to provide for this. The two towers discharge water at a combined rate--determined by the input flow to the towers of 185,000 galls/min--less the evaporative losses sustained by the tower. These losses are computed at 4,850 galls/min (291,000 galls/hr) for full capacity operation. The total outflow from both towers is approximately 180,150 galls/min (10,809,000 galls/hr).

Even with the cooling towers, the cooling lake still receives 80% of the annual heat load. The discharge of the additional waste heat into the cooling lake is estimated to increase lake temperature by approximately 8°C

when the cooling towers are not operating (Wisconsin Public Service Commission 1974).

The cooling lake has a 2.47-m hydrostatic head above the remaining wetlands. Seepage through the bottom of the cooling lake has changed the remaining wetlands adjacent to the west dike and has helped to dilute the ash effluent as it flows to Rocky Run Creek.

Water from the cooling lake is pumped and circulated continuously through the plant steam condenser and returned to the lake. Similarly, water for all the plant service water requirements is pumped from the lake. All the service water, less small losses in process, are returned to the lake. Another use of cooling water is the ash sluicing operation. The water that is pumped for the sluicing process hydraulically conveys the particulate material to the 28.4-ha ash basin.

Water from the Wisconsin River is used to maintain a uniform level in the cooling lake; it is pumped almost continually into the lake to make up for losses from evaporation and leakage.

All heat rejected from the steam condensers and the service equipment of Unit I is dissipated from the cooling lake. Approximately 200,000 galls/min of lake water is circulated through the main steam condenser. This water receives a chlorination treatment aimed at maintaining a residual chlorine content between 0 and 0.1 ppm in the water at the condenser outlet. This chlorination is an intermittent injection type of treatment used to prevent the growth of undesirable organisms in the water.

Approximately 15,000 galls/min of cooling lake water (also treated with chlorine) is used as service water for plant equipment--in addition to the water required for the steam generator and condenser and the ashpit drainage.

The potable water required for human consumption and steam generation make-up is obtained from two deep drilled wells located near Columbia Units I and II. This well water is pumped to a storage tank and through parallel sand filters before undergoing chemical treatment to produce the required quality of feedwater going to the boilers.

The filtered well water is treated in a demineralizer system having a designed capacity of 260 galls/min. Each parallel treating-train has a strong acid-cation exchanger, one decarbonator, a strong base-anion exchanger, and, finally, a mixed-bed polisher. While this arrangement was selected for the type of water available from the test well, it leaves room for modification to suit the actual composition or purity of water desired as final product.

The turbine in each unit is a tandem-compound unit requiring at full capacity a steam flow of almost 3,800,000 lb/hr at 2,400 lb/inch² gauge pressure (psig) and 1,000°F. The generator is a 617,800 KVA, 9.9 power factor, 22,000 volt, 3-phase, 60-cycle, 3,600 rpm, inner-cooled, self-excited unit.

Several supporting subsystems are required by the turbine generator. These include the pressure lubricating-oil system, the high-pressure control fluid system, the excitation system, the hydrogen gas system, and a stator cooling system.

The generator of Unit II feeds through an additional main power transformer to the two existing 345-kV buses located in the switch yard. Four 345-kV oil circuit-breakers were added to facilitate the transmission of additional power. The original three dead-end towers which support transmission lines were increased to six. The length of the low-profile bus was increased about 15%.

The water system existing for Unit I was utilized for Unit II--with some additions and alterations. The intake channel, pump house and pipelines to the cooling lake were not altered for operation of Unit II, although water flow was increased to meet the demands of the two-unit operation. The cooling lake itself was not altered for two-unit operation and its water level has stayed the same.

The steam requirements for operation of each of the two turbines are provided by a controlled-circulation, dry-furnace bottom, drum-type pulverized coal-fired unit. Each steam generating unit produces 3,800,000 lb/hr of steam at a pressure of 2,400 psig and temperature of 1000°F.

No. 2 oil is burned to warm the coal boiler in each unit during start-up. Approximately 2,000 galls of fuel are used during the warm-up of each unit, which lasts about 6 hr. The oil is shut off after coal is fed to the furnace and ignited. Complete shut-down and start-up of the two boilers are usually scheduled twice a year.

The burners require a little more than 1×10^6 lb/hr of primary or feed air which is heated in two vertical-shaft air-heaters, moved by two fans through the heater to the pulverizers, and on into the burners.

Secondary warm combustion air of about 3.7×10^6 lb/hr is required and is provided by two forced draft fans. This air is preheated by a heat-exchanger before entry into the air heaters. Air is drawn into the plant through lowered walls.

Two circulating pumps of 92,500 galls/min (5,550,000 galls/hr) each were added to the existing screenhouse to provide for operation of Unit II. In order to have a standby unit, one additional 18,500 galls/min (1,110,000 galls/hr) low-head service-water pump was installed. These new pumps move water from the screen house to the condensor in Unit II.

A flow of about 15,000 galls/min (900,000 galls/hr) is necessary to meet the service water needs for Unit I. Of this amount, approximately 14,500 galls/min (870,000 galls/hr) is used to cool plant equipment other than the main condensor. An additional flow of 14,500 galls/min (870,000 galls/hr) for plant cooling is required by Unit II. The remaining 500 galls/min (30,000 galls/hr) flow for miscellaneous plant needs is adequate to serve both units.

Water from the low pressure service water system is used to remove bottom ash and precipitated fly ash from Units I and II. However, Unit II does not require as much water for sluicing ash as Unit I. Some of the fly ash collected from Unit II in the electrostatic precipitators is transported to storage-bins pneumatically. Approximately 50,000 tons of fly ash are expected to be sold annually. This is equivalent to 35% of single-unit output and 17 to 18% of total output of both units.

The incremental flow of sluice water for Unit II operation is estimated to average 640 galls/min (or 38,400 galls/hr). The ash sluice from Unit II is pumped into the already existing ash basin for settling. After entering the ash pond ditch, the water is pumped into the discharge ditch built for single-unit operation to service Unit I. The only change is an increased rate of flow. The average flow is estimated to be 2,316 galls/min (138,960 galls/hr).

The incremental needs for Unit II are served by the two water wells associated with Unit I which were not altered. A third deep well was drilled and equipped to serve as a standby. With Unit II on-line, water use is approximately double that of single unit operation.

The water supply system for Unit I also is used for Unit II. It was augmented by the addition of a third steam demineralizer train which provides an additional 250 galls/min (15,000 galls/hr).

In two-unit operation, the blowdown rate of 50 galls/min (3,000 galls/hr) from the upper steam drum of the steam generating unit is doubled. Boiler cleaning solutions, which are discharged to the ashpit, and oil water wastes, which are trucked off the site to an approved disposal area, have approximately doubled.

Two electrostatic precipitators were constructed for Unit II that are similar to the pair for Unit I. Flue gases from the combustion chamber of each of the two steam generating units are withdrawn by two induced draft fans at the rate of about 5.5 million lb/hr at a temperature of 760°F. These gases are passed over an economizer and then blown to two electrostatic precipitators which are mounted at each side of the base of the chimney stack. The gases pass through the air heater and exit the stack at 275°F. The precipitators are 99.5% efficient. The particle size of the typical ash is $< 50 \mu$.

The system installed for Unit I monitors air quality for the combined operation of both units. The ash handling system for Unit II includes additional piping for the pneumatic transport of fly ash into a loading

bin. This system was installed to facilitate the sale of the fly ash, which is projected to be 50,000 tons/yr. The rest of the ash is sluiced into the ash basin.

The flow rates in and out of the ash basin have increased but the ash basin and the mode of operation have not been altered by the addition of Unit II. The ash-sluice is the principal source of water flow into the ash basin. The ash-sluice flow rate was increased to an average of a little over 1,640 galls/min (98,400 galls/hr) by the addition of Unit II.

HISTORY OF THE PROJECT

In 1969, several Wisconsin electric power companies applied to the Wisconsin Public Service Commission for permission to construct a 500 MW coal-burning power-plant near Portage in Columbia County, Wisconsin. At the time, information and documentation on the environmental impacts of large projects such as power-plants were practically non-existent.

A recognition of the need for such information led researchers at the Institute for Environmental Studies of the University of Wisconsin-Madison to propose a study to measure the impact of the proposed power plant. In 1971, with support from the three utility companies, they began a pre-construction study of the environmental characteristics of the site. These studies were continued during the construction and early operational phases of the plant from January 1971 until July 1975.

In 1975, the U.S. Environmental Protection Agency recognized the unique research opportunity that existed at this site--as well as the potential nationwide application of the findings. The agency awarded the project a 3-yr grant to continue and expand the research funded by the power companies. This research project, "The Impact of Coal-Fired Plants on the Environment," has involved over 100 persons in 24 research areas.

THE DATA CENTER

One of the goals of this large-scale study was to integrate the various subprojects thereby allowing examination of major questions that might be neglected in separately funded projects. To meet this goal, the Columbia study used the continuous-synthesis approach, in which the study is conceived and developed as a unit and synthesis proceeds throughout. The continuous-synthesis approach dictated the need for a data center to coordinate central collection, transfer, storage, and documentation of all data pertaining to the study. These efforts were designed to: (1) eliminate unnecessary duplication of data gathering; (2) facilitate the transfer of data and other information from one disciplinary subproject to another; and (3) organize the data so that maximum use could be made of it. To provide an efficient system for holding, processing, and exchanging data within the project, the Data Center for the Columbia Site Impact Study was established in June 1976.

The Data Center's first role was to survey the data generated by the subprojects, and to identify future data sets and potential uses for the

data base. During this stage the data center analysts worked closely with the investigators of each subproject to develop the overall structure of the data base.

In the next stage--the evaluation stage--the Data Center identified the functional description, the system design strategy (including the structure of the files) and a duplication plan. These were presented to the investigators and were approved. Utilizing the existing Data Base Management System, located at the Madison Academic Computer Center, University of Wisconsin-Madison, the Data Center maintains the final copy of the data base on a labeled tape. The data sets can be directly accessed by specifying the identification number (for example, C8B1).

During the implementation stage special attention was paid to the integrity of the data. For each data set all entries were verified, and where applicable, computer programs were executed to identify out-of-sequence records. In addition, a copy of the data was forwarded to the investigators for further reviews and suggestion. The suggested structure changes were implemented and errors were corrected. After a data set was approved, it was copied to the permanent records of the data base. For security purposes, the computerized data base is stored at the Madison Academic Computer Center and two additional copies are archived in separate locations. In addition, all the tapes are in read-only mode, thus, no changes can be made by the user. To prevent the use of the data without permission, the Data Center processes all requests and contacts the investigator for approval of the request.

SECTION 2

CONCLUSIONS AND RECOMMENDATIONS

The data center of the Columbia impact study provides a range of services. Primarily, this center makes the data accessible to different users, both internal and external to the project. The data are standardized, adjusted, organized into forms suited to modern storage and retrieval procedures, and stored with systematized names as an information base. In addition, information about the data and the quality assurance are prepared. By means of this process of data preparation, the data center enables interdisciplinary evaluation of the data, enhances the data's usefulness to other investigators, and helps to minimize duplication. The data center, with its expertise in data handling and data analysis, also provides assistance in computer services and statistical analyses to investigators. In addition, the centralized data center makes it easier to extend the data base to include complementary data from related studies. The data center can disseminate data from this base of information, manipulating and processing the data as necessitated by user requirements. This use of the data base improves coordination of ongoing and planned programs, eliminates duplication in the collection of data, and provides calibration for models.

For the first 18 months after it was established, the Data Center was organized around three functions. First, the Data Center facilitated uniformity and smoothness in processing and exchanging data. Wherever feasible, the Data Center developed standardized procedures for putting information into computer-usable form. In this role, the Data Center listed all the data available with information about the form of the data, the parameters measured, and the dates and location of acquisition. Second, the Data Center was a physical location that centralized and made accessible the data itself and basic documentation of the data. Third, by utilizing the statistical and programming expertise of its staff, the Data Center provided statistical analysis and summary output to different subprojects in the study.

PROCEDURE FOR INCOMING DATA

The actual data were made available to the Data Center in two major forms: (1) computer readable form such as cards, files, and magnetic tapes; and (2) non-compatible forms such as notes, tables, figures, slides, photographs, and maps.

For data available to the Center in computer-readable form, the following procedure was followed. The Data Center staff first transferred

the data obtained from other computers to the Data Center computer. The data format was checked to assure conformity with the criteria for data presentation established by the Data Center. In many cases data was reformatted to meet a standard national format (such as SAROAD) for easy understanding by potential users.

The same considerations in formatting were made when numerical data were made available in non-computer readable form. Here, the data were formatted and entered into the computer by a Data Center staff member.

Staff also examined incoming data in order to correct any readily apparent errors. An initial check by the Center was a safeguard against certain kinds of errors, such as mistakes in keypunching, sequence, and formatting; this check also prevented the omission of data and the inclusion of numbers outside the supposed limits. At the same time, the Data Center staff grouped the data received into convenient periods of time. For example, if for one particular parameter many readings had been taken, accumulation of data for 1 yr could be inconveniently large. In other cases, all data for several years could be conveniently grouped together.

THE DATA BOOK

Beginning in early 1978, the Data Center adopted a broader approach, adding to its earlier functions the task of compiling a data book for the entire study. The objectives of this endeavor include: (1) to compile an inventory of information and data from the Columbia Generating Station impact study; (2) to make data available to secondary scientific users for re-analysis, synthesis, or theoretical studies; and (3) to effect a transfer of ecosystem and environmental data to policy-makers and non-scientific users.

For preparation of the data book sections, the Data Center established the following procedure. Each subproject was assigned one staff member who read all the relevant semi-annual reports and met with all the investigators involved to familiarize themselves with the methodology and data collection processes. After several interviews, the staff member defined and listed all the data sets gathered by the subproject. The staff member also checked for data collected by other sources that were used by the subproject investigators in order to identify all the data sets available to the Columbia impact study.

The orientation of the data book was developed in response to five questions that were raised regarding suitable storage and documentation of data: (1) Who are the potential users of the data? (2) What data should be included in the data base? (3) What is the most suitable method of presentation of the results? (4) What storage and retrieval methods should be executed? and (5) What should be included in the documentation of the data?

(1) In compiling the data book, four categories of potential users were addressed: (a) investigators who will conduct longitudinal studies on the

impact of the Columbia Generating Station; (b) ecological research and modeling investigators who depend on the analysis and synthesis of a large number of parameters; (c) investigators looking for tools for impact assessment; and (d) the non-scientific user community. The cost of acquiring new data for purposes of research and environmental monitoring is rising steadily. This puts increasing value on existing data for use in policy analysis, environmental assessment, and the calibration of models. This potential secondary use gives additional value to the data consolidated in the data base of the Columbia power plant impact study.

(2) The Data Center created an inventory of all the information collected in the Columbia study. This collection included ecosystem and ecological data, as well as new methods that were developed for assessing environmental impacts. Data were not included when the investigators doubted their validity or reliability.

(3) Presentation of results followed the principle that data must be as free from interpretation as possible and in such a format that uncertainties in the data can be assessed independently. Observational data were cast such that they could be re-analyzed in terms of a different hypothesis than that presented by the investigators.

(4) For the purposes of storage and retrieval, two major forms of data were identified: computer-readable form and visual data. Computerized data are stored on tape in the tape utility system of the Univac 1110 computer at the Madison Academic Computer Center (MACC), University of Wisconsin-Madison. The storage system was designed so that users with access to MACC could retrieve the data directly without the assistance of the Data Center staff. For users within and outside the University of Wisconsin-Madison, the Data Center staff can send data on cards, printout, or tapes. Visual data, including maps, graphs, slides, and pictures, are stored in the Data Center of the Columbia impact study. Reproductions of all available data can be obtained from the Data Center upon permission from the principal investigator involved, and defrayment of certain costs.

(5) The basic demand of a secondary user of data is the availability of proper documentation. To meet this need the data book documents each data set in six sections: a data abstract, an explanation of data access, a data sample, a quality assurance analysis, supporting documents, and qualifications of the investigators. Data abstracts include the names of the investigators, a data summary, a short summary of experimental method, and dates. Data access describes the method of accessing the data, including information about the form of the data and for data stored on computer file, number of records, field description, indication of missing data, percent recovery, and underlying corrections. In the data sample section, a representative sample of the data is presented for long data sets and the entire data set is reproduced for small data sets.

The quality assurance report of each data set provides the necessary information for an assessment of the validity and reliability of the measurements in that set. Although the topics vary according to the

different requirements of each data set, most quality assurance reports address the objectives of the data set; description of the system studied; description of methods, equipment, and procedures; and an evaluation of the performance of the equipment. The supporting documents sections cite sources that either describe the data or present the results of the studies. These documents include internal documents such as the semi-annual progress reports of the Columbia study. Many of these internal publications contain extensive discussion of problems encountered by the investigators that are relevant to the quality of the data. The report on each data set also lists the names and qualifications of the experimenters and investigators who were responsible for data collection.

Each data set is classified as either a data set or an auxiliary data set. The difference between the two categories lies in the importance or the origin of the data set. The data set is classified as auxiliary if the information it contains is designed to facilitate understanding of some other data set. A quality assurance report is not included for auxiliary data sets.

The data sets are organized according to the subprojects and the specific studies carry unique identification numbers. Each ID number is a combination of the following: The first character, C, identifies the Columbia study; The second character is the subproject number (8 through 18) and corresponds to the chapter in the data book; The next character identifies the different studies carried out by each subproject. Some of the studies produced several data sets which are identified by a number following the study letter. Thus, data sets that have the same study identification were conducted in a similar manner and used the same sampling locations. In addition, on some occasions, several studies utilized the same sampling or monitoring sites. A user can identify these studies by consulting the map which accompanies each data set.

Both data sets and auxiliary data sets can be classified into four categories: (1) numeric data-base, (2) non-computerized data, (3) integrated hardware/software system, and (4) model. Most of the data consists of numerical data bases. These data sets present numerical values for known variables. The identification information for such numerical data-bases may be alphanumeric; therefore, the corresponding entries may contain alphanumeric characters among numeric values. The non-computerized data contain graphs, charts, maps, slides, and pictures. These data are stored in the Data Center and are available upon request. The integrated software/hardware systems have programs that were developed in the Columbia project. Some of the entries in this category may require modification to a different hardware system. A "model" is considered to be a mathematical function that has been theoretically developed for, and applied to, an ecosystem problem--to arrive at condensed results for specific parameters; results that can be used for prediction and simulation. The models that emerge from the Columbia impact study will be documented and published in separate reports.

PROCEDURE FOR DATA RETRIEVAL

There are two major ways in which potential users can retrieve computer-readable data: (1) for users with direct access to the Madison Academic Computer Center at the University of Wisconsin-Madison, the MACC system can be used; and (2) for users outside the University of Wisconsin-Madison the data must be retrieved by Data Center personnel. The Data Center can make the data sets available as computer cards, printout, or computer tapes. In addition, Data Center personnel can provide statistical analyses and summary outputs of the data.

SECTION 3.

AQUATIC CHEMISTRY

This subproject dealt with changes in water quality resulting from activities related to electric power production at the Columbia Generating Station. The emphasis was to characterize the dissolved major and minor elements that are controlled by metastable equilibrium. Specific objectives were: (1) to monitor changes in the concentrations of dissolved elements in the aquatic system at the Columbia site, and (2) to understand and characterize the heterogeneous reactions which describe the metastable equilibrium established in the aquatic system by the major and minor constituents of fly ash.

Pursuant to objective 1 two on-site surveys were conducted. The data collected in these surveys are presented in data sets C3A1 and C3A2. Data set C3A1 (Quality of the water system surrounding the Columbia Generating Station 1976-77) describes the results of a monthly survey (February 1976 to April 1977) of the aquatic system at the Columbia site. Data set C3A2 (Element flow in the ashpit of the Columbia Generating Station 1977) is the result of an intensive 1-month sampling regime (September 1977) to model elemental flow of major and minor elements.

In relation to objective 2 three laboratory experiments were conducted and are data sets C3B1, C3B2, and C3B3. Data set C3B1 (Fly ash equilibrium leaching experiments) presents the results of an experiment on elemental leaching with time. Data set C3B2 (Leaching and electrophoretic mobility of fly ash under different pH values) shows concentration and mobility of the dissolved elements as a function of pH. Data set C3B3 (Total elemental concentration fly ash from the Columbia Generating Station) presents the total elemental concentration in Columbia fly ash.

The investigators were Anders Andren, Associate Professor; Marc Anderson, Assistant Professor; Nicholas Loux, Research Assistant; Robert Talbot, Research Assistant; Department of Civil and Environmental Engineering (Water Chemistry), University of Wisconsin-Madison. The report was compiled by Saya Shacham, Data Analyst, Water Resources Center.

DATA SET C3A1: QUALITY OF THE WATER SYSTEM SURROUNDING THE COLUMBIA
GENERATING STATION (1976-77)

Data Summary

Investigators--

N. Loux and A. Andren.

Abstract--

This data set contains the results of an 11-month survey designed to study the trace element chemistry of the aquatic system at the generating station site. Water samples were collected monthly from June 1976 to April 1977 at 15 sampling stations around the power plant: in the Wisconsin River, the cooling lake, the ashpit, and the ashpit drain and water samples were analyzed for dissolved potassium (K), sodium (Na), calcium (Ca), magnesium (Mg), sulfate (SO_4), nitrate (NO_3), nitrite (NO_2), orthosilicate (SiO_4), total reactive phosphate (PO_4), oxygen (O), chloride (Cl), and zinc (Zn). In addition, pH, temperature, particulates and dissolved organic carbon (C) were measured. Later, a number of samples were analyzed for iron (Fe), aluminum (Al), copper (Cu), and chromium (Cr).

Dates of Research--

June 1976-April 1977.

Data Form--

Computer file containing 232 units with three card-images/unit.

Data Format

Field Description--

Card #1

<u>Column</u>	<u>Format</u>	<u>Description</u>
1-2	I2	Month
3-4	I2	Year
6-8	I3	Station number
9	I1	Depth; 1=surface, 2=mid-depth, 3=bottom
11-14	F4.1	pH level
16-18	I3	Temperature in degrees Celsius
20	I2	Indicator code for Na ¹
22-26	F5.1	Na concentration in mg/liter

¹In the indicator code, 0 indicates that the entry which follows is the exact measured value; 1 indicates that the entry which follows is greater than the exact value.

28	I1	Indicator code for K
30-34	F5.2	K concentration in mg/liter
36	I1	Indicator code for Ca
38-42	F5.1	Ca concentration in mg/liter
44	I1	Indicator code for Mg
46-50	F5.2	Mg concentration in mg/liter
52	I1	Indicator code for Fe
54-58	F5.3	Fe concentration in mg/liter
60	I1	Indicator code for Al
62-66	F5.3	Al concentration in mg/liter
68	I1	Indicator code for Cd
70-75	F5.4	Cd concentration in mg/liter
80	I1	Image sequence, 1 for Card #1

Card #2

1-2	I2	Month
3-4	I2	Year
6-8	I3	Station number
9	I1	Depth; 1=surface, 2=mid-depth, 3=bottom
12	I1	Indicator code for Cl
14-18	F5.1	Cl concentration in mg/liter
20	I1	Indicator code for Cr
22-26	F5.3	Cr concentration in mg/liter
28	I1	Indicator code for Cu
30-34	F5.4	Cu concentration in mg/liter
36	I1	Indicator code for SiO ₄
38-42	F5.2	SiO ₄ concentration in mg/liter
44	I1	Indicator code for O
46-50	F5.2	O concentration in mg/liter
52	I1	Indicator code for SO ₄ -S
54-58	F5.1	SO ₄ -S concentration in mg/liter
60	I1	Indicator code for NO ₂ -N
62-66	F5.3	NO ₂ -N concentration in mg/liter
68	I1	Indicator code for NO ₃ -N
70-75	F5.3	NO ₃ -N concentration in mg/liter
80	I1	Image sequence, 2 for Card #2

Card #3

1-2	I2	Month
3-4	I2	Year
6-9	I3	Station number
9	I1	Depth; 1=surface, 2=mid-depth, 3=bottom
12	I1	Indicator code for total alkalinity
14-18	F5.1	Total alkalinity expressed as the concentration of CaCO ₃ in mg/liter
20	I1	Indicator code for HCO ₃
22-26	F5.1	HCO ₃ in mg/liter
28	I1	Indicator code for CO ₃
30-34	F5.1	CO ₃ in mg/liter
36	I1	Indicator code for total PO ₄ -P

38-43	F6.1	Total PO ₄ -P concentration in µg/liter
45	I1	Indicator code for total dissolved PO ₄ -P
47-52	F6.1	Total PO ₄ concentration in µg/liter
54	I1	Indicator code for dissolved reactive PO ₄ -P
56-61	F6.1	Dissolved reactive PO ₄ concentration in µg/liter
80	I1	Image sequence, 3 for Card #3

Missing Data--

Missing data are indicated by 999.

Data Sample

The sample presented here is 5 units, 196 to 200 of the 232 units included in the complete data set C3A1.

123456789012345678901234567890123456789012345678901234567890																								
0377	1011	11.2	7	0	490.	0	3.1	0	12.6	0	0.2	0	0.78	0	11.4	0	0.0019	1						
0377	1011	0	16.5	0	0.061	0	0.030	0	3.43	0	12.8	0	999	0	999	0	999	2						
0377	1011	0	187.7	0	999	0	999	0	101.	0	22.	0	4.	0	999	0	999	3						
0377	1012	11.2	7	0	480.	0	2.8	0	11.2	0	0.1	0	0.89	0	11.4	0	0.0024	1						
0377	1012	0	16.3	0	0.058	0	0.034	0	3.44	0	12.8	0	999	0	999	0	999	2						
0377	1012	0	198.7	0	999	0	999	0	86.	0	16.	0	3.	0	999	0	999	3						
0377	1013	11.2	7	0	482.	0	5.8	0	11.9	0	0.4	0	0.86	0	11.4	0	0.0024	1						
0377	1013	0	17.4	0	0.064	0	0.032	0	3.45	0	12.8	0	999	0	999	0	999	2						
0377	1013	0	203.7	0	999	0	999	0	96.	0	9.	0	3.	0	999	0	999	3						
0377	1021	11.2	9	0	483.	0	2.8	0	11.2	0	2.8	0	0.86	0	11.4	0	0.0021	1						
0377	1021	0	16.5	0	0.060	0	0.030	0	3.40	0	9.0	0	999	0	999	0	999	2						
0377	1021	0	203.7	0	999	0	999	0	89.	0	18.	0	4.	0	999	0	999	3						
0377	1031	11.3	9	0	556.	0	3.1	0	7.8	0	0.1	0	1.05	0	12.8	0	0.0024	1						
0377	1031	0	18.5	0	0.070	0	0.036	0	3.61	0	11.0	0	999	0	999	0	999	2						
0377	1031	0	240.5	0	999	0	999	0	108.	0	41.	0	6.	0	999	0	999	3						

Quality Assurance

Objectives--

The purpose of the survey was to study the trace element chemistry of the aquatic system at the generating station site. For this purpose the aquatic chemistry group established a program to monitor dissolved K, Na, Ca, Mg, SO₄, NO₃, NO₂, SiO₄, total and reactive PO₄, O, Cl, and Zn in the water at the site. In addition, pH, temperature, particulates, and dissolved organic (C) were measured. Later, some samples were analyzed also for Fe, Al, Cu, and Cr. Samples were collected monthly for 11 months (June 1976 to April 1977).

Sampling Sites--

Based on a study of water circulation patterns around the coal-fired generating station, 15 sampling stations were selected. The stations were chosen to represent the various processes taking place in the aqueous environment. The locations of these stations (Figure 4) include (1) the Wisconsin River (104, 108); (2) the inflow settling basin of the cooling pond (107); (3) the cooling water intake to the station (105); (4) the

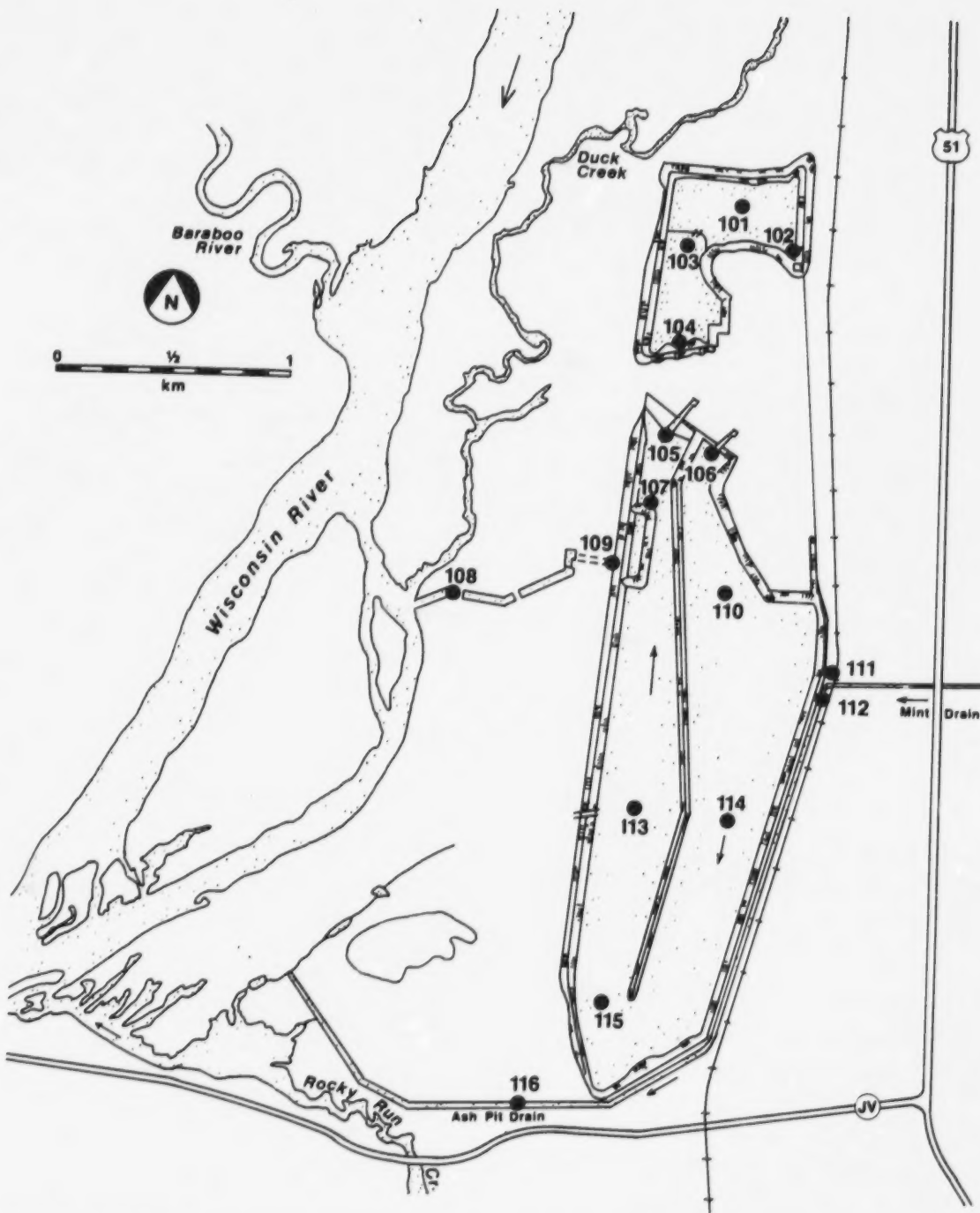


Figure 4. Location of 15 water sampling stations at the Columbia Generating Station.

cooling water outflow from the station (106); (5) the cooling pond (110, 113, 114, 115); (6) the ash pond (101, 102, 103); and (7) the ash pond drainage ditch (111, 112, 116).

Sample Collection--

Water samples were collected with a Kemmerer water sampler and placed in 2-liter polyethylene bottles. These bottles had been previously washed in 1:1 HCl. For each station one sample each was collected for the surface, the middle, and the bottom. In cases where the sampling station was too shallow, only one sample was collected.

Analytical Procedure--

Water samples were immediately brought back to the laboratory and filtered through 0.4- μ m Nucleopore filters. A substance is "dissolved" if it passes through the filter. Each sample was analyzed once for each element. Wherever the procedure called for use of standards, five or six standards were used. The standards were prepared from analytical reagent grade chemicals prepared by the experimenter.

Ca, Mg, K, and Na Analyses--Dissolved concentrations of Ca, Mg, Na, and K were measured by flame atomic absorption (Perkin-Elmer 303 and Perkin-Elmer 603), using a method listed in Standard Methods for Examination of Water and Wastewater (American Public Health Association 1971). Sample concentrations were calculated by using a standard curve prepared from mixed stock solutions of elements. Lanthanum was added to act as a releasing agent for minimizing interference from Al, PO_4 , and SiO_4 . Standards contained La in the sample proportion. The detection limit for the samples was 0.1 mg/liter for Ca, 0.02 mg/liter for Mg, 0.002 mg/liter for Na, and 0.05 mg/liter for K.

Al, Cd, Cr, Cu, and Fe Analyses--Flameless atomic absorption was employed to determine dissolved concentrations of Al, Cd, Cr, Cu, and Fe. Analyses were conducted with a Perkin-Elmer Model 603 AAS equipped with an HGA-2100 graphite furnace following the method described by Perkin-Elmer (1977). Precision for all above elements was 10%.

SiO_4 Analysis--The dissolved reactive silica was analyzed by the Strickland and Parsons (1968) procedure. This is a spectrophotometric technique based on the colorimetric determination of a blue silicomolybdate complex after reduction with -methylaminophenol sulfate. The detection limit was 0.01 mg/liter. It was measured as SiO_4 and is expressed as SiO_4 in the data.

SO_4 Analysis--Sulfate concentrations were analyzed by the turbidometric technique listed by the American Public Health Association (1971). A Bausch and Lomb spectronic 100 spectrophotometer with a 5-cm cell was used to determine the absorbance of the $BaSO_4$ suspensions. The detection limit was 1 mg/liter, and the precision was 10%.

NO₂ and NO₃ Analyses--Nitrite and NO₃ (previously reduced with a Cd reduction column) were analyzed by the procedure detailed in the American Public Health Association Standard Methods (1975). A Bausch and Lomb Spectronic 100 spectrophotometer with a 1-cm cell was used to measure the absorbance of the azo compound formed with sulfanilamide and N-(1-naphthyl)-ethylene diamine dihydrochloride. The detection limit was 0.01 mg/liter. Both NO₂ and NO₃ were reported as N.

PO₄ Analysis--Total PO₄ was analyzed by the Murphy-Reilly procedure, a spectrophotometric technique based on the colorimetric determination of a blue phosphomolybdenum complex after digestion with H₂SO₄ and (NH₄)₂S₂O₈. Analyses were conducted with a Bausch and Lomb Spectronic 100. The dissolved reactive PO₄ was analyzed by the above procedure without digestion but with filtration. Precision was 2%, and the detection limit was 0.003 mg/liter. Phosphate determinations are expressed as P.

Cl Analysis--Chloride was analyzed using the method described by the American Public Health Association (1971), a technique which employs a titrimetric procedure using AgNO₃ with a K₂CrO₄ indicator. The AgNO₃ standard solution was standardized with a NaCl solution.

O₂ and Temperature Analyses--A Yellow Springs Instrument Model 54 DO meter was used to determine temperature and dissolved oxygen during the study. The thermometer was compared several times with a laboratory thermometer, and the oxygen probe was calibrated three times using the Winkler DO technique. Prior to field analyses, O-saturated distilled water in the laboratory was analyzed and values were compared with theoretical DO concentrations. Precision was $\pm 0.5^{\circ}\text{C}$ for temperature and ± 0.5 mg/liter for DO.

Alkalinity Analysis--Alkalinity was measured by a titrimetric procedure according to the method described by the American Public Health Association (1971). The standard Na₂SO₄ solution was precalibrated with a Na₂CO₃ solution. The detection limit was 3 mg/liter.

pH Analysis--A Beckman portable pH meter was used for pH determinations. Before analyses were made the instrument and combination electrode were precalibrated with standard pH buffers of 10.00, 6.86, and 4.01. The precision for pH was ± 0.1 pH units.

Investigators and Supporting Documents--

The experiment was conducted by Nicholas Loux. At the time of the experiment he was working toward a Ph.D. degree in Water Chemistry at the University of Wisconsin-Madison. The experiment was conducted in the Water Chemistry Laboratory at the University of Wisconsin-Madison under the supervision of Dr. A. Andren.

Aquatic chemistry. In: Documentation of environmental change related to the Columbia Electric Generating Station. Institute for Environmental Studies, Reports 66, 69, 82, and 92, University of Wisconsin-Madison.

Andren, A., M. Anderson, N. Loux, and R. Talbot. 1980. Element flow in aquatic systems surrounding coal-fired power plants. U.S. Environmental Protection Agency, Cincinnati, Ohio. 84 p.

DATA SET C3A2: ELEMENT FLOW IN THE ASHPIT OF THE COLUMBIA GENERATING STATION (1977)

Data Summary

Investigators--

N. Loux and A. Andren.

Abstract--

An intensive sampling program was carried out during September 1977 to evaluate the Schindler (1975) model for describing element flow through the ashpit of the Columbia Generating Station. Water samples were collected at nine stations in the cooling pond, the ashpit, the ashpit discharge, and in two wells west of the ashpit. Analytical determination was made for pH, alkalinity, SO₄, CO₃, Cl, P, Si, Na, Mg, K, Ca, Fe, Mn, Cu, Cd, Zn, Al, Pb, As, and B.

Dates of Research--

13 September 1977 and 27 September 1977.

Data Form--

Computer file containing 32 units with three card-images per unit.

Data Format

Field Description--

Card #1

<u>Column</u>	<u>Format</u>	<u>Description</u>
1-2	I2	Month
3-4	I2	Year
6-8	I3	Station number
9	I1	Depth; 1=surface, 2=mid-depth, 3=bottom
11-14	F4.1	pH level
16-18	I3	Temperature (°C); 1=surface, 2=mid-depth, 3=bottom
20	I2	Indicator code for Na ²
22-26	F5.1	Na concentration in mg/liter
28	I1	Indicator code for K

²In the indicator code, 0 indicates that the entry which follows is the exact measured value; 1 indicates that the entry which follows is greater than the exact value.

30-34	F5.2	K concentration in mg/liter
36	I1	Indicator code for Ca
38-42	F5.2	Ca concentration in mg/liter
44	I1	Indicator code for Mg
46-50	F5.2	Mg concentration in mg/liter
52	I1	Indicator code for Fe
54-58	F5.3	Fe concentration in mg/liter
60	I1	Indicator code for Al
62-66	F5.3	Al concentration in mg/liter
68	I1	Indicator code for Cd
70-75	F5.4	Cd concentration in mg/liter
80	I1	Image sequence, 1 for Card #1

Card #2

1-2	I2	Month
3-4	I2	Year
6-9	I3	Station number
9	I1	Depth; 1=surface, 2=mid-depth, 3=bottom
12	I1	Indicator code for Cr
14-18	F5.3	Cr concentration in mg/liter
20	I1	Indicator code for Cu
22-26	F5.3	Cu concentration in mg/liter
28	I1	Indicator code for SiO ₄
30-34	F5.1	SiO ₄ concentration in mg/liter
36	I1	Indicator code for Cl
38-42	F5.2	Cl concentration in mg/liter
44	I1	Indicator code for SO ₄ -S
46-50	F5.1	SO ₄ -S concentration in mg/liter
52	I1	Indicator code for As
54-58	F5.3	As concentration in mg/liter
60	I1	Indicator code for B
62-66	F5.2	B concentration in mg/liter
80	I1	Image sequence, 2 for Card #2

Card #3

1-2	I2	Month
3-4	I2	Year
6-9	I3	Station number
9	I1	Depth; 1=surface, 2=mid-depth, 3=bottom
12	I1	Indicator code for total alkalinity
14-18	F5.1	Total alkalinity expressed as concentration of CaCO ₃ in mg/liter
20	I1	Indicator code for HCO ₃
22-26	F5.1	HCO ₃ concentration in mg/liter
28	I1	Indicator code for CO ₃
30-34	F5.1	CO ₃ concentration in mg/liter
80	I1	Image sequence, 3 for Card #3

Missing Data--

Missing data are indicated by 999 preceding the indicator code.

Data Sample

The sample presented here is 4 units, 1 to 4, of the 32 units included in data set C3A2.

1234567890123456789012345678901234567890123456789012345678901234567890	
130977 2011 8.1 23 0 10.0 0 2.1 0 42. 0 21.0 0 0.009 0 0.018 1 0.0001	1
130977 2011 1 0.001 0 0.010 0 3.5 0 12.4 0 20. 0 0.004 0 999	2
130977 2011 0 156. 0 156. 0 0.	3
130977 2021 11.5 23 0 512. 0 3.8 0 8. 0 0.3 0 0.016 0 34.9 0 0.0023	1
130977 2021 0 0.072 0 0.020 0 6.8 0 14.3 0 64. 0 0.110 0 999	2
130977 2021 0 649. 0 0. 0 482.	3
130977 2031 11.5 20 0 691. 0 4.3 0 37. 0 0.4 0 0.016 0 46.9 0 0.0046	1
130977 2031 0 0.133 0 0.020 0 5.2 0 11.8 0 146. 0 0.199 0 999	2
130977 2031 0 370. 0 0. 0 144.	3
130977 2032 11.5 20 0 691. 0 4.0 0 40. 0 0.4 0 0.017 0 44.0 0 0.0030	1
130977 2032 0 0.127 0 0.020 0 5.2 0 11.9 0 145. 0 0.201 0 999	2
130977 2032 0 356. 0 0. 0 134.	3

Quality Assurance

Objectives--

The study was carried out to evaluate the Schindler (1975) model for describing element flow through the ashpit of the Columbia Generating Station. By measuring flow rates, dissolved substances, and particulates of selected elements, sedimentation rates, and rate of precipitate formation, the data fit the equation for predicting element flow in the ashpit. This data set was designed to study flow rates of dissolved substances and particulates for selected elements. Samples were collected at nine stations in the cooling pond, the ashpit, the ashpit discharge, and at two wells west of the ashpit. Analytical determinations were made for pH, alkalinity, SO₄, total CO₃, Cl, total P, Si, N, Mg, K, Ca, Fe, Mn, Al, Cu, Cd, Zn, Pb, As, and B. Much of the work was coordinated with the Mass Balance Subproject. The data could not be applied to the Schindler (1975) model since the concentrations of the elements were too variable.

Sampling Sites--

Based on a study of water circulation patterns in the ash pond and the ashpit drainage, nine sampling stations were selected. The location of these stations (Figure 5) were: (1) the cooling water intake to the station (105); (2) the first basin of the ash pond (202, 203); (3) the second basin of the ash pond (204, 205, 206, 207); and (4) the ash pond drainage (208, 209). In addition, water samples were taken for two wells west of the ashpit.

Sample Collection--

Same as data set C3A1.

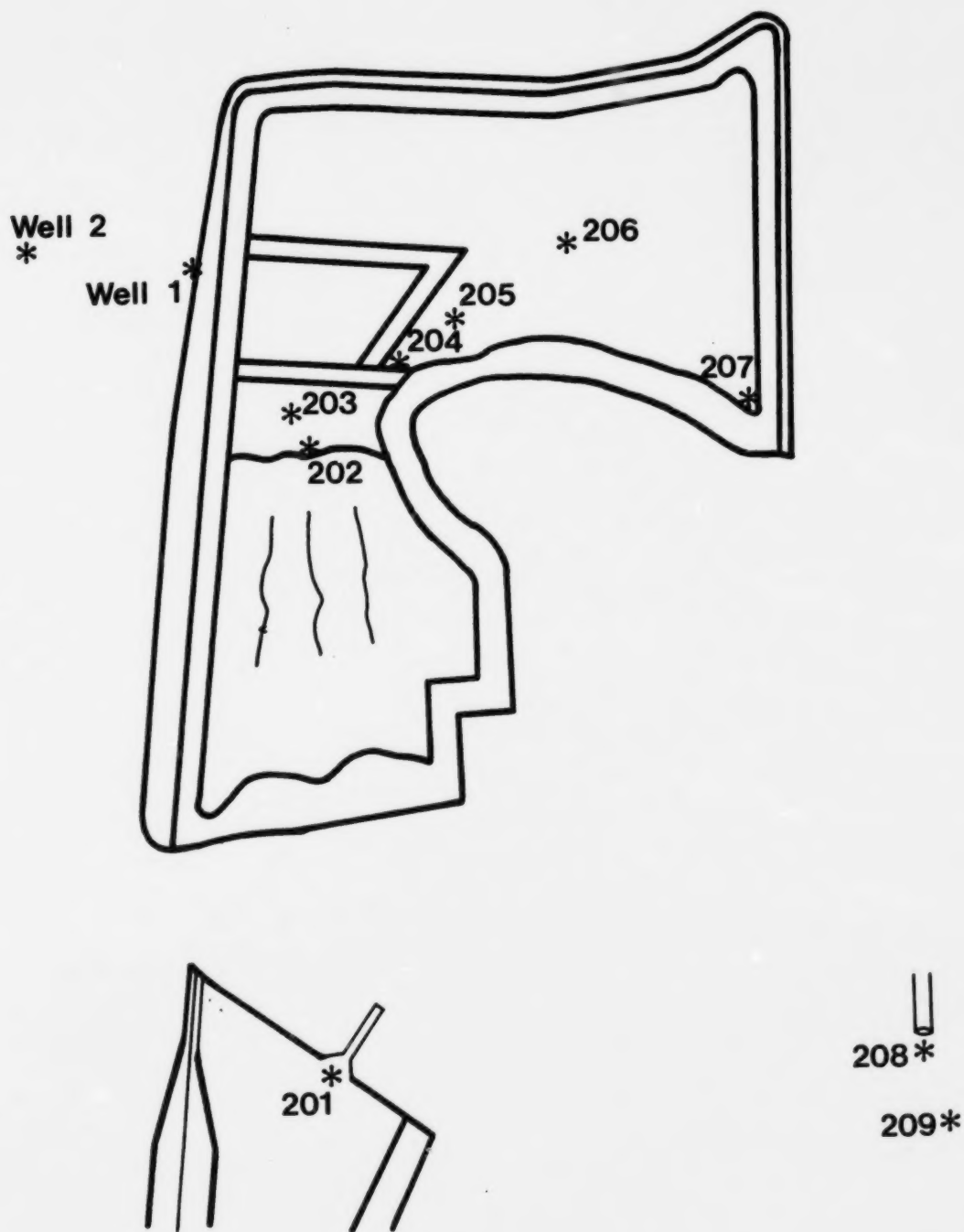


Figure 5. Location of 11 water sampling stations in and near the ashpit of the Columbia Generating Station.

Analytical Procedure--

Same as data set C3A1.

Investigators--

Same as data set C3A1.

Supporting Documents

Same as data set C3A1.

DATA SET C3B1: EXPERIMENTS OF FLY ASH EQUILIBRIUM LEACHING

Data Summary

Investigators--

R. Talbot and M. Anderson.

Abstract--

This data set contains duplicate equilibrium leaching experiments conducted on four samples of fly ash from the Columbia site. The study was designed to investigate the heterogeneous reactions that describe the metastable equilibria in an aqueous system. Concentrations of dissolved Al, Ca, Cd, Fe, K, Mg, Na, P, Si, and pH were measured 15 times over a period of 6 months.

Dates of Research--

1975-1977.

Data Form--

Computer file containing 60 units with one card-image per unit.

Data Format

Field Description--

<u>Column</u>	<u>Format</u>	<u>Description</u>
1	I1	Sample location of fly ash: 1=fly ash submerged, 2=freshly deposited, 3=dewatered delta fly ash, 4=hopper fly ash
3-4	I2	Time
6	I1	Time unit; 1=minutes, 2=hours, 3=weeks, 4=months
10-14	F5.2	pH ³
16-19	F4.2	-log [Al]

³Values for pH and all elements are mean values for duplicate experiments.

21-24	F4.2	-log [Ca]
28-29	F4.2	-log [Cd]
31-34	F4.2	-log [Fe]
36-39	F4.2	-log [K]
41-44	F4.2	-log [Mg]
46-49	F4.2	-log [Na]
51-54	F4.2	-log [P]
56-59	F4.2	-log [Si]

Missing Data--

None.

Data Sample

The sample presented here is 10 units, 1 to 10, of the 60 units included in data set C3B1.

1234567890123456789012345678901234567890123456789

1	15	1	10.48	4.29	3.63	8.78	7.49	4.93	5.34	5.54	6.01	5.01
1	30	1	10.60	4.09	3.57	8.98	7.09	4.81	5.00	5.76	5.87	4.82
1	45	1	10.61	4.04	3.53	9.08	7.45	4.66	4.94	5.76	5.82	4.75
1	1	2	10.56	4.00	3.51	9.14	7.70	4.49	4.86	5.77	5.80	4.70
1	2	2	10.58	3.92	3.46	9.14	7.20	4.45	4.72	5.68	5.73	4.57
1	6	2	10.30	3.84	3.37	8.95	7.07	4.30	4.46	5.63	5.57	4.43
1	12	2	10.10	3.83	3.33	8.91	7.52	4.27	4.35	5.72	5.48	4.55
1	24	2	9.61	3.91	3.29	8.87	7.49	4.20	4.19	5.73	5.41	4.56
1	48	2	8.92	4.08	3.24	8.86	7.60	4.13	3.94	5.72	5.60	4.67
1	72	2	8.74	4.10	3.19	8.82	7.79	4.03	3.75	5.67	6.04	4.77

Quality Assurance

Objectives--

The goals were to investigate the heterogeneous reactions which describe the metastable equilibria established in an aqueous system by the major and minor constituents of fly ash. An equilibrium approach was used in this laboratory experiment to determine the processes responsible for the distribution of elements between solid phase and solution.

Sampling Sites and Collection--

Fly ash was obtained from selected locations and was categorized for use in the laboratory experiments (see Figure 6) as follows:

- (1) Fly ash collected under water off the end of the ash delta (submerged);
- (2) Freshly deposited fly ash on the ash delta (wet delta);
- (3) Fly ash deposited on the ash delta but dewatered (dry delta);
- (4) Fly ash from stages II and III of the hopper bins (hoppers).

Categories (1-3) were obtained during June and July 1976. Category (4) was obtained on 5 September 1975. The fly ash was collected from numerous

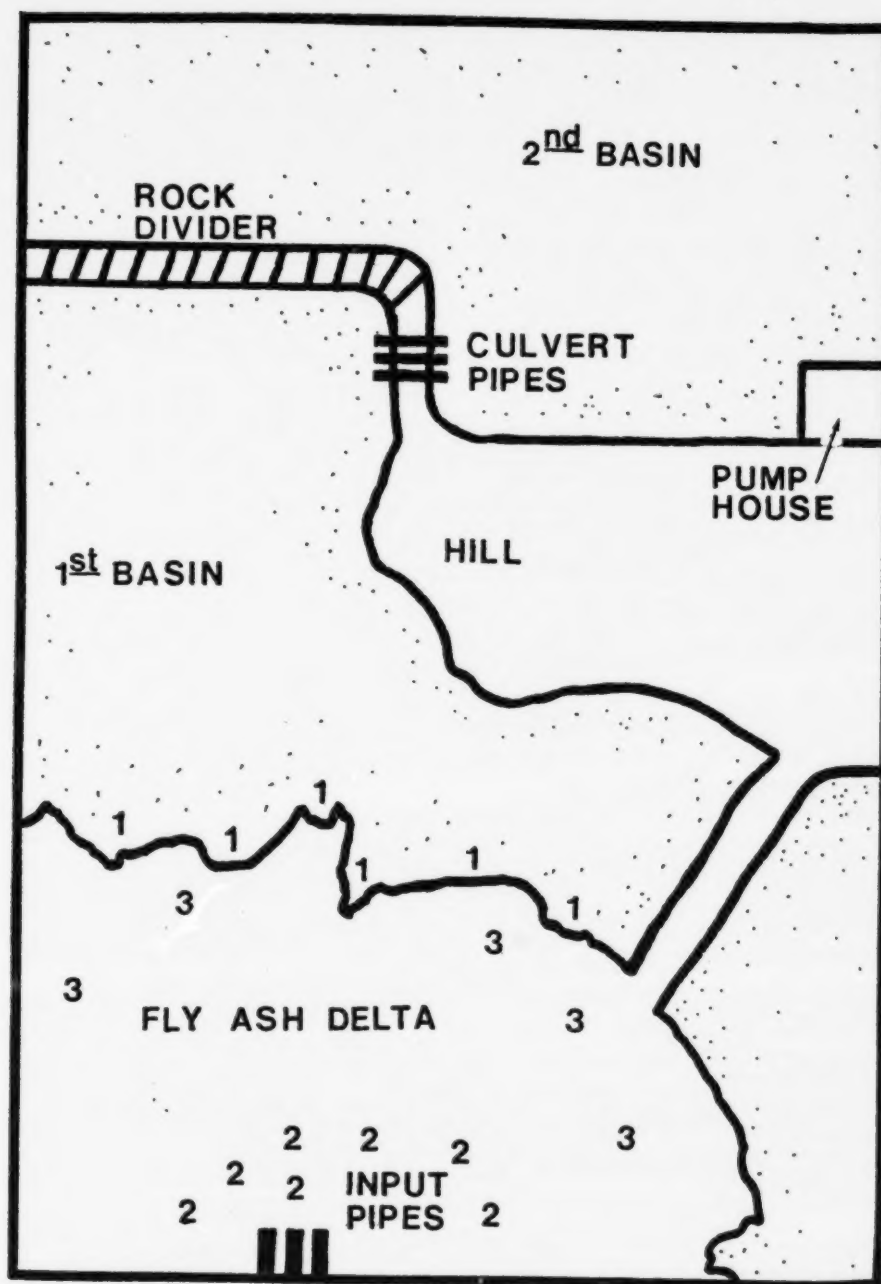


Figure 6. Location of fly ash sampling stations in the fly ash basin of the Columbia Generating Station (1-- off delta stations; 2-- wet delta stations; 3-- dry delta stations).

sites (at least eight for each category) to insure sample homogeneity. The fly ash was air-dried in polyethylene containers loosely covered with Al foil to avoid contamination from dust and air-borne debris in the laboratory. After 1 week, the fly ash was hand-sieved through a U.S. Standard No. 325 mesh sieve which had been cleaned with 10% HNO_3 and soaked in double distilled water for 24 hr. The fraction collected consisted of particles $> 44 \mu\text{m}$ in diameter. The fly ash was stored in a dessicator until used.

The water samples were collected from the ash pond by submerging a clean conventional polyethylene bottle to a depth of approximately 30 cm. The bottle was thoroughly rinsed with pond water several times before the actual sample was collected. Filtration of these samples was performed in the laboratory within 6 hr of collection.

Sample Preparation--

Filtration--Filtration was used to differentiate dissolved and solid phases. All filtrations were conducted through $0.4\text{-}\mu\text{m}$ Nucleopore filters utilizing a Millipore polycarbonate apparatus. This apparatus was cleaned by soaking in 10% HNO_3 for 24 hr and then in double distilled water for an additional 24 hr. The filters were stored in a polyethylene container filled with 10% HNO_3 , but were removed 24 hr before use and soaked in double distilled water.

The filtration procedure involved first passing 200 ml of double distilled water through the apparatus and filter. Next, a 25 ml aliquot of the sample was filtered and discarded and the remaining sample was filtered. This method resulted in low filtration blanks compared to the dissolved elemental concentrations in the samples. Rinsing the filtering apparatus between samples with dilute acid greatly increased the loss of dissolved elements during filtration due to retention on the apparatus.

Sample Storage--Conventional or linear polyethylene bottles were used to store water samples. These containers were rinsed thoroughly with distilled water and filled with 10% HNO_3 . After soaking for 24 hr, the bottles were rinsed, filled with double distilled water, and allowed to soak for an additional 24 hr. Clean bottles were air-dried upside-down on a drying rack before being used to store filtered water samples.

Each sample filtrate was divided for storage or analysis immediately following filtration. The filtrate aliquots designated for analysis of Ca, Cd, Fe, K, Mg, and Na were acidified with HNO_3 acid to 0.5% and stored at 4°C in polyethylene bottles cleaned as previously described. Several acidified double distilled water blanks were stored at the same time. The remaining filtered portion was not stored but analyzed immediately for Al, P, and Si. Nucleopore filters with the collected solids were placed in acid-washed plastic Millipore petri dishes and stored in a dessicator at room temperature (20°C).

Analytical Procedure--

Elemental analyses were carried out as described below. The analysis for each element was repeated at least 10 times on 10 different days.

Al, P, and Si Analyses--Dissolved Al was determined colorimetrically (using a Bausch and Lomb spectronic 100 spectrophotometer) after complexation with 8-quinolinolate and extraction into chloroform using the procedure described by Okura et al. (1962). Flameless atomic absorption was utilized for low Al concentrations ($<10^{-6}$). Comparative analysis of the two techniques indicated that a small amount ($<5\%$) of the Al existed as polymerized species at the time of analysis. Thus, the colorimetric procedure gave a good estimation of total dissolved Al.

Concentrations of dissolved reactive P were measured by the procedure outlined in the Manual of Methods of Chemical Analysis of Water and Wastes (U.S. Environmental Protection Agency 1974). No interference from the high Si concentration in the samples was observed.

The procedure of Strickland and Parsons (1968) as modified by Vigon (1976) was used to determine dissolved reactive Si. For a few samples longer reaction times were used since the reaction of polymers of higher molecular weights with molybdates is a function of their first-order depolymerization rate. However, no significant increase in Si concentration was observed. Precision for all colorimetric analyses was $\pm 5\%$.

Ca, Mg, Na, and K Analyses--Dissolved concentrations of Ca, Mg, Na, and K were measured by flame atomic adsorption with methods adopted from the U.S. Environmental Protection Agency (1974). Sample concentrations were calculated using a standard curve prepared from a mixed stock solution of the elements. LaCl_3 was added to Ca and Mg samples (5,000 ppm La) to act as a releasing agent for minimizing interference from Al, P, and Si. Standards contained LaCl_3 in the same proportion as the samples.

Sodium was determined directly without ionization control. Addition of LiCl or KCl to the samples provided more uncertainty from large blank values than did direct sample aspiration which naturally contained varying degrees of ionization control. Potassium, however, was determined after addition of LiCl (1,500 ppm Li). Apparently, the low Na concentrations in the samples offered little ionization control for K, since samples measured without LiCl yielded concentrations 65 to 70% lower. Precision for all flame analysis was $\pm 1\%$.

Storage of Ca, Mg, and K samples for 6 months showed no change in solution concentration. Sodium loss to the container walls was apparent after 1 week. Ultrasonic agitation of several samples for 15 min. produced the originally measured dissolved concentration. This technique was applied to approximately 30% of the samples and covered the concentration range of the samples. The technique revealed a reproducible loss of 15% by adsorption to conventional and linear polyethylene bottles. An empirical factor was applied to the remainder of the samples to account for this loss

because of the larger number of samples and the narrow Na concentration range encountered in the samples.

Al, Cd, and Fe Analyses--Flameless atomic absorption was employed for the determination of low concentrations of dissolved Al, Cd, and Fe. Analyses were conducted with a Perkin-Elmer Model 603 AAS equipped with an HGA-2100 graphite furnace. Analyte concentrations were measured after electrothermal atomization and were corrected for background absorption. The operating conditions were optimized using actual samples rather than standards containing only the analyte. Pyrolytically-coated graphite tubes were employed in all analyses.

Sample concentrations were calculated using a standard curve prepared from a stock solution of each element. Iron and Al standards were prepared by dissolving the metal in 1% HNO_3 or HCl , respectively. A certified atomic absorption standard was utilized for Cd. Linear concentration ranges for each element were found to be: 1 to 50 ppb Al, 0.05 to 0.10 ppb and 0.10 to 0.3 ppb Cd, and 1.0 to 3.0 ppb Fe (using 20 μ liter injections). Precision for Cd was $\pm 2\%$, for Fe $\pm 3\%$, and for Al $\pm 5\%$.

Standard additions performed in the linear concentration range of each element showed the concentration to be within 5-6% of that determined from the standard curve. Instrumental difficulty hindered by simultaneous background correction has been discussed by Kahn and Manning (1972) and shown to have some intrinsic error; that is, the method assumes that atomization conditions remain the same for background and sample determinations. A few analyte concentrations were tediously determined with simultaneous background correction despite the instrumental problems. These concentrations indicated that the subtraction method produced accurate values for the actual dissolved concentration.

pH--A Sargent-Welch (Model S-30072-25) low-junction potential combination electrode combined with an Orion Research (Model 701) digital pH meter was used for pH measurements. The electrode was calibrated with standard buffers in the pH range of the sample to be measured. Precision of the readings was 0.1 pH units (± 6 mv). Electrode equilibration (typically 5 to 15 min.) with the sample was indicated by the plateau response shown on a strip-chart recorder. Sodium error was assumed negligible even though solutions of low hydrogen activity were encountered. A nomograph supplied by the electrode manufacturer indicated the validity of this assumption.

Investigators--

The experiment was conducted by Robert W. Talbot. At the time of the experiment he was working toward an M.S. degree in Aquatic Chemistry at the University of Wisconsin-Madison. The experiment was conducted in the Water Chemistry Laboratory at the University of Wisconsin-Madison under the supervision of Dr. M. Anderson.

Supporting Documents

Aquatic chemistry. In: Documentation of environmental change related to the Columbia Electric Generating Station. Institute for Environmental Studies, Reports 66, 69, 82, and 92, Univ. of Wisconsin-Madison.

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Talbot, Robert W. 1977. Heterogeneous equilibria in a fly ash pond. M.S. Thesis, University of Wisconsin-Madison. 161 p.

DATA SET C3B2: LEACHING AND ELECTROPHORETIC MOBILITY OF FLY ASH UNDER DIFFERENT pH VALUES

Data Summary

Investigators--

R. Talbot and M. Anderson.

Abstract--

This data set contains the results of a leaching experiment. The leaching was conducted separately for each of the four fly ash samples collected from the Columbia ash pond under 12 different conditions pH. For each of the fly ash samples, electrophoretic mobility (μ) and dissolved elemental compositions (Al, Ca, Cd, Fe, K, Mg, Na, P, and Si) were measured separately for each of the 12 pH values.

Dates of Research--

1975-1977.

Data Form--

Computer file containing 48 units with one card-image/unit.

Data Format

Field Description--

<u>Column</u>	<u>Format</u>	<u>Description</u>
1	F1	Sample location of fly ash: 1=fly ash submerged, 2=freshly deposited delta fly ash, 3=dewatered delta fly ash, 4=hopper fly ash
3-7	F5.2	pH
9-13	F5.2	Electrophoretic mobility (expressed as micron/sec/v/cm)

15-18	F4.2	-log [Al]
20-23	F4.2	-log [Ca]
25-28	F4.2	-log [Cd]
30-33	F4.2	-log [Fe]
35-38	F4.2	-log [Mg]
40-43	F4.2	-log [Na]
45-48	F4.2	-log [P]
50-53	F4.2	-log [Si]

Missing Data--

Missing data are indicated by 999.

Data Sample

The sample presented here is 12 units, 1 to 12, of the 48 units included in data set C3B2.

1234567890123456789012345678901234567890123

1	1.17	999	3.42	3.39	7.48	4.57	3.40	4.94	5.18	3.49
1	2.22	-1.84	3.45	3.37	7.98	4.63	3.41	5.37	5.21	3.47
1	4.20	1.29	3.69	3.43	8.77	5.79	3.47	5.77	6.57	3.76
1	5.10	2.10	4.34	3.53	8.72	6.73	3.58	6.03	5.76	3.98
1	5.68	1.75	5.39	3.64	8.65	7.71	3.79	5.48	5.57	4.38
1	6.56	1.19	6.52	3.63	8.72	7.84	3.81	5.47	5.13	4.41
1	7.66	-0.13	5.64	3.65	8.56	7.95	3.84	5.32	5.79	4.52
1	8.33	-0.73	4.83	3.64	8.29	7.75	3.86	4.82	5.39	4.55
1	8.88	-0.76	4.68	3.68	9.03	7.55	3.87	5.15	5.96	4.55
1	10.00	-0.80	4.22	3.68	9.18	7.49	3.90	5.88	5.49	4.45
1	11.03	-1.26	4.08	3.59	9.25	7.16	4.44	5.91	5.61	4.14
1	12.22	-1.42	3.79	3.56	9.75	7.01	4.75	5.58	5.97	3.77

Quality Assurance

Objectives--

The experiment was designed to study dissolved elemental concentration in fly ash as a function of pH. An attempt was made to determine the solid phases that control the major chemical elements and to determine the surface changes of fly ash under different pH conditions to explain the behavior of minor elements.

Sampling Sites and Collection--

Same as data set C3B1.

Sample Preparation--

Same as data set C3B1.

Analytical Procedure--

The analytical procedures used were the same as in data set C3B1 with the following addition.

Electrophoretic Mobility (μ)--The electrophoretic mobility of fly ash suspensions was determined by measuring the zeta-potential with a Lazer-Zee Meter (Pem-Kem Corporation). This value, when divided by 14.2, yields the electrophoretic mobility (μ) of the particle. The factor (14.2) is a calibration constant for the instrument. For each pH value five mobility measurements were taken. Reproducible measurements were obtained, but the accuracy of the technique is unknown.

Investigators--

Same as data set C3B1.

Supporting Documents--

Same as data set C3B1.

DATA SET C3B3: TOTAL ELEMENTAL COMPOSITION OF FLY ASH FROM THE COLUMBIA GENERATING STATION

Data Summary

Investigators--

R. Talbot and M. Anderson.

Abstract--

This data set contains values of total concentrations of major and minor elements in four different fly ash samples collected at the Columbia Generating Station site. The values are the mean of duplicate digestions and are expressed as ng/mg fly ash.

Dates of Research--

1975-1977.

Data Form--

Computer file containing four units with one card-image/unit.

Data Format

Field Description--

<u>Column</u>	<u>Format</u>	<u>Description</u> ⁴
1	I1	Sample location of fly ash: 1=fly ash submerged, 2=freshly deposited, 3=dewatered delta fly ash, 4=hopper fly ash
3-8	I6	Al
10-15	I6	Ca
17-22	I6	Fe
24-29	I6	K
31-36	I6	Mg
38-43	I6	Na
45-50	I6	P
52-57	I6	Si
59-64	I6	Zn

Missing Data--

None.

Data Sample

This is the complete data set C3B3.

12345678901234567890123456789012345678901234567890123456
1 62880 114398 30375 4615 34438 2564 1188 230493 83
2 57183 117063 26786 4008 34325 3413 1250 206746 69
3 65106 111644 31786 4288 34736 2754 1207 224351 79
4 63355 118243 32790 4491 37560 2067 1094 216415 76

Quality Assurance

Objectives--

The main goal of the experiment was to identify total concentration of major and minor elements in the fly ash. The concentrations were compared to dissolved concentrations reported in data set C3B1 and data set C3B2.

Sampling Sites and Collection--

Same as data set C3B1.

Sample Preparation--

Same as data set C3B1.

⁴Values for all elements are mean of duplicate experiments and expressed as ng/mg fly ash.

Analytical Procedure--

Same as data set C3B1.

Fly Ash Total Digestion Procedure--

To obtain total concentrations of major and minor elements in each of the four fly ash samples, an acid digestion technique was required. A major problem associated with the decomposition of inorganic siliceous materials is the loss of silica by volatilization as a fluoroide.

Reviewing various methods for decomposition of siliceous materials, Langmyhr and Paus (1968) suggest that heat-resistant (130°C) plastic vessels may suffice for these digestions. A satisfactory method was developed for digesting 25 mg of fly ash in a linear polyethylene bottle below the boiling point of HF (112°C). The bottles containing the fly ash for digestion were placed on a hot sand bath at 100°C $\pm$ 3°C and digestion was conducted as follows: (1) 2 ml of HNO₃ (70%) was added and the solution heated for 1 hr; (2) 2 ml of HF (48%) was added slowly and the solution heated for 2 hr; and (3) 1 ml of HCl (38%) was added and the solution heated for 1 hr.

After cooling, the solution was diluted with double distilled water so as to contain 10% acid, and elemental analysis was performed by colorimetry or flame atomic absorption spectroscopy.

Using the aforementioned decomposition method, values for the elemental composition of National Bureau of Standards (NBS) Standard Fly Ash are included in Table 2. All sample digestions were conducted in duplicate, whereas the results for the NBS Standard are based on five replicate digestions.

TABLE 2. DIGESTION RESULTS FOR NBS STANDARD REFERENCE
FLY ASH #1633 AND FLY ASH FROM THE COLUMBIA GENERATING STATION

Element	NBS fly ash (%) ^a	Columbia fly ash (%) ^b
Al	12.7 $\pm$ 0.5	12.4 $\pm$ 0.02
Ca	4.7 $\pm$ 0.6	4.6 $\pm$ 0.02
Cd	< 0.001	< 0.001
Fe	6.2 $\pm$ 0.3	6.0 $\pm$ 0.02
Mg	1.8 $\pm$ 0.4	1.3 $\pm$ 0.08
Na	0.32 $\pm$ 0.06	0.26 $\pm$ 0.01
K	1.61 $\pm$ 0.15	0.89 $\pm$ 0.03
Si	21 $\pm$ 2	24.7 $\pm$ 0.06
Zn	0.021 $\pm$ 0.002	0.020 $\pm$ 0.05

^aOndov et al. (1975).

^bMean values of five replicate digestions ($\pm$ relative standard deviation).

Investigators--

Same as data set C3B1.

Supporting Documents

Same as data set C3B1.

REFERENCES

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SECTION 4

TRACE ELEMENTS

This subproject investigated the impact of the Columbia Generating Station on the concentrations of trace elements in the environment. The investigators, using neutron activation analysis techniques they had developed, attempted to accurately measure the concentrations and distributions of several trace elements (including potentially toxic ones) resulting from particulate fallout on soil and water around the plant.

The principal goals were: (1) to document the concentrations and distribution of trace elements in the environment resulting from particulate fallout and (2) to determine if trace elements emitted from the generating station are bioaccumulated by plants and animals.

Specific objectives for the data collected were: (1) to document trace element concentrations in soil to determine if the spatial distribution and flux of fly ash can be measured in the environment; (2) to monitor the impact of trace elements in fly ash on plant life in the vicinity of the power plant; and (3) to document trace element concentrations in small organisms to determine how the elements are taken up and excreted.

In relation to objective 1, one study was conducted. The data collected in this study are presented in data set C4A1. Data set C4A1, (The concentration of trace elements in Columbia County soil) documents the results of trace element analyses of soil samples collected in 1973 between 4.8 and 11.2 km from the Columbia Generating Station.

In relation to objective 2, one study was conducted. The data collected in the study are presented in data set C4B1. Data set C4B1, (The concentration of trace elements in oak leaves near the Columbia Generating Station (1973-76)) presents the results of a study which monitored foliar uptake from fly ash deposition and/or elemental vapor released from the Columbia Generating Station.

In relation to objective 3, two studies were conducted. The data collected in these studies are presented in data sets C4C1 and C4C2. Data set C4C1 (Concentrations of trace elements in aquatic organisms collected near the Columbia Generating Station (1974-76)) presents a study in which arthropod samples collected around the Columbia Generating Station were analyzed by nondestructive neutron activation analysis. Data set C4C2, (Trace elements in amphibians from the ashpit drain of the Columbia Generating Station (1974-76)), presents another study of trace element levels in organisms as determined by nondestructive neutron activation

analysis. Both studies examined the feasibility of using trace element composition of aquatic organisms as indicators of environmental quality, specifically in connection with exposure to ash effluent from the power plant.

The investigators were Philip A. Helmke, Associate Professor, Wayne P. Robarge, Research Assistant; Robert D. Koons, Research Assistant; and Myles B. Schoenfield, Research Assistant; Department of Soil Science, University of Wisconsin-Madison. The report was compiled by Hilary McLellan and Saya Shacham, Data Analysts, Water Resources Center.

DATA SET C4A1: THE CONCENTRATION OF TRACE ELEMENTS IN COLUMBIA COUNTY SOIL

Data Summary

Investigators--

W. P. Robarge and P. A. Helmke.

Abstract--

This data set contains a trace-element analysis of six soil samples collected on 17 September 1973. The samples were collected from six sites located 4.8 and 11.2 km from the Columbia Generating Station. The data contain the concentrations of As, Ba, Cl, Co, Cr, Eu, Fe, Hf, La, Lu, Mn, Na, Rb, Sb, Sc, Se, Ta, Tb, Th, W, and Yb for each of the six samples.

Date of Research--

1973.

Data Form--

Computer file containing 21 units with two card-images per unit.

Field Description--

Card #1

<u>Column</u>	<u>Format</u>	<u>Description</u>
1-2	A2	Trace element under analysis
4-15	F12.6	Trace element conc. (ppm) Station D-8-1
17-28	F12.6	Uncertainty (Station D-8-1)
30-41	F12.6	Trace element conc. (ppm) Station C-26-1
43-54	F12.6	Uncertainty (Station C-26-1)
56-67	F12.6	Trace element conc. (ppm) Station W-18-1
69-80	F12.6	Uncertainty (W-18-1)

Card #2

1-2	A2	Element under analysis
4-15	Fl2.6	Trace element conc. (ppm) Station FW-36-1
17-28	Fl2.6	Uncertainty station FW-36-1
30-41	Fl2.6	Trace element conc. (ppm) Station D-12-1
43-54	Fl2.6	Uncertainty (Station D-12-1)
56-67	Fl2.6	Trace element conc. (ppm) Station W-5-1
69-80	Fl2.6	Uncertainty (Station W-5-1)

Data Sample

The sample presented here is 16 records, 1 to 16, of the 21 units in the data set C4A1.

1234567890123456789012345678901234567890123456789012345678901234567890

AS	3.7	0.2	4.9	0.4	4.8	0.4
AS	4.9	0.3	2.4	0.2	4.5	0.4
BA	460.	30.	580.	30.	360.	20.
BA	320.	30.	190.	30.	200.	30.
CE	26.9	0.8	31.4	0.9	21.5	0.6
CE	61.	3.	31.	2.	35.	2.
CO	5.8	0.2	7.3	0.3	5.3	0.2
CO	3.8	0.2	1.37	0.06	4.6	0.2
CR	80.	17.	100.	22.	57.	13.
CR	60.	10.	24.	5.	59.	10.
EU	0.54	0.05	0.60	0.05	0.38	0.03
EU	0.376	0.011	0.186	0.011	0.366	0.010
FE	13840.	420.	15710.	470.	14560.	440.
FE	11100.	200.	5425.	100.	11560.	200.
HF	8.7	0.4	10.7	0.4	4.8	0.2
HF	5.3	0.3	2.9	0.2	3.1	0.2

Quality Assurance

Objectives--

The purpose of the study was to monitor fly ash deposition in soils in the vicinity of the Columbia Generating Station.

Sampling Sites--

Samples of soil dust were collected at six sites around the Columbia Generating Station (Figure 7). Since there are predominantly easterly winds in the area, most of the sites were located east of the power plant where fallout from the plume most likely would be deposited. One site was located west of the power plant.

Sample Collection--

At each of the six sites, an area of approximately 50 x 50 m was selected. In each of the areas three 1 ft² plots were selected at random. After the litter was removed, 10 random samples of the top 1 inch of soil were collected from each square with a 1-in.-diameter polyethylene coring tool, and were then placed in bags. The samples were air-dried, crushed and sieved.

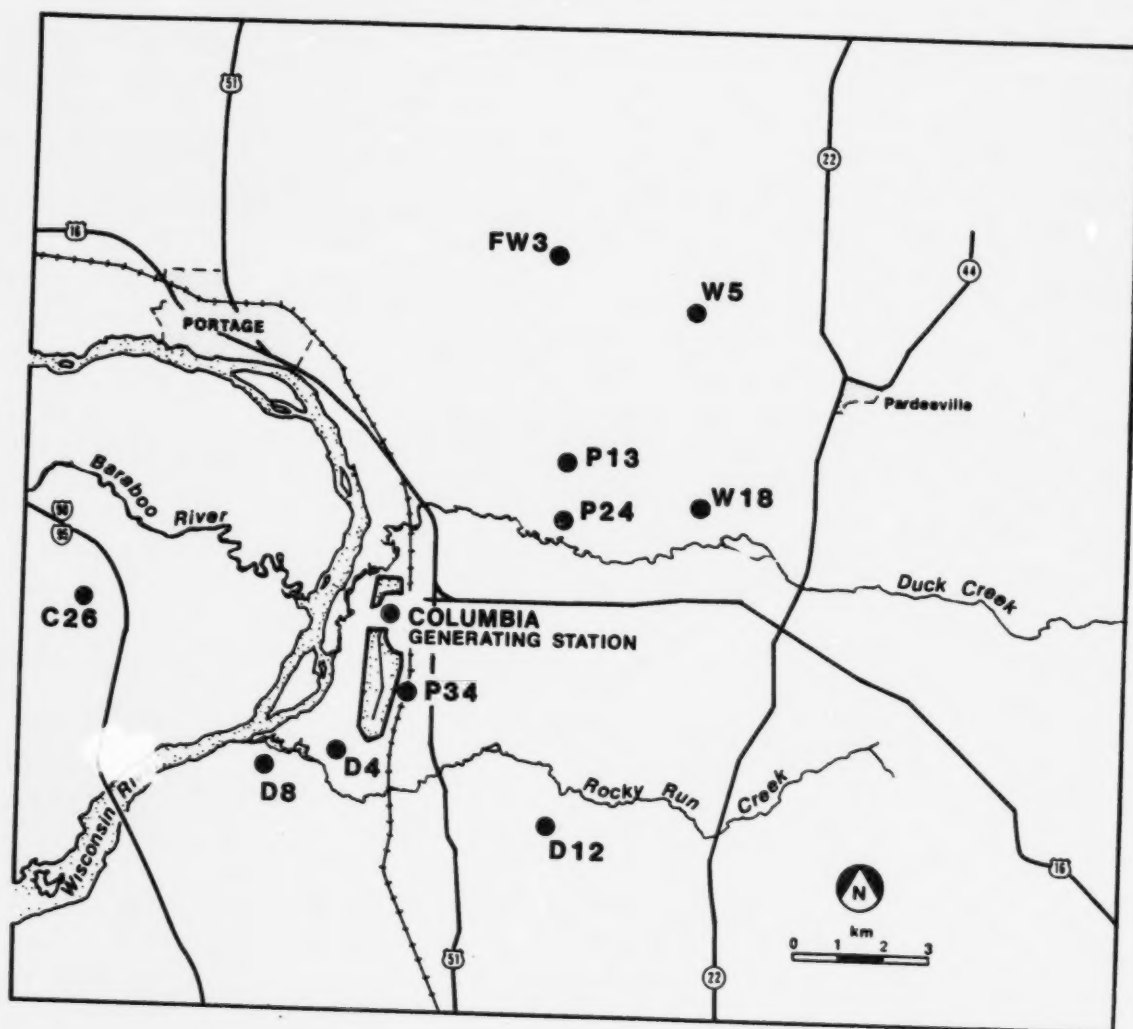


Figure 7. Sampling sites for the collection of soil.

Analytical Procedures--

A procedure of radiochemical neutron activation developed by the investigators was used. This procedure provides an accurate measurement of the concentrations of the trace elements As, Cd, Co, Cu, Ga, Hf, Hg, Mn, Na, Sb, Sc, Se, Zn, and the rare-earth elements, simultaneously, in samples of biological materials, coals, or sediments weighing <100 mg. The method involves neutron irradiation of the sample, followed by chemical digestion with a carrier added for each element, and chemical separation of the elements into groups suitable for gamma-ray spectrometry. The chemical yields are measured for each element.

This method provides a high degree of immunity from contamination (essentially zero blank levels) and a high level of sensitivity (detection limits <1 ppm).

Quality assurance was provided by three types of comparisons: (1) replicate analysis of National Bureau of Standards (NBS) bovine liver samples, (2) analyses of four standard soil samples from the Canadian Certified Reference Material Project, and (3) analyses of United States Geological Survey (USGS) standard rocks.

Prior to analysis, replicate analysis of the NBS bovine liver samples (No. SRM-1577) was performed. The values obtained by means of the investigators' procedure agreed with the calculated uncertainties given by NBS for the nine elements analyzed. Accuracies at the 90% confidence level for elements in the liver include: $\pm 10\%$ for Cu, Na, and Zn; 10 to 25% for As, Co, Hg, La, Mn, and Se; and 25 to 50% for Ce, Sb, Sc, and Sm. The uncertainties for results obtained on most samples range from $\pm 5\%$ to $\pm 10\%$ because most of the elements are present at higher concentrations in these samples than in the bovine liver sample.

Subsequent to the analysis of the bovine liver samples, the investigators further refined their analytical techniques. In the earlier analysis of the bovine liver, samples were dissolved by repeated refluxing with a mixture of HNO_3 and H_2SO_4 . The samples were dissolved in a Teflon bomb at temperatures from 120° to 150°C . The acids used varied with the type of sample. This procedure reduces the amount of time needed for the chemical separations.

In addition to the comparison with previously analyzed bovine liver standard, four standard soil samples were analyzed concurrently with the Columbia soil samples. Four standard soils were prepared and sent by the Canadian Certified Reference Materials Project, including: (1) SO-1 from the C-horizon of a Rideau clay, a Typic Udorthent; (2) SO-2 from the B-horizon of a Humic Cryorthod developed in sandy glacial till; (3) SO-3 from a calcareous glacial till parent material of the Guelph series, a Mollic Hapludalf; and (4) SO-4 from the A-horizon of a Typic Haploboroll developed in silty, lacustrine deposits. Two bottles of each standard soil was received. Five subsamples, each weighing approximately 100 mg, were obtained from each bottle and analyzed for 25 elements to test for inhomogeneities within samples and to demonstrate the use of neutron activation.

A third comparison was made to assess the accuracy of readings obtained for the Columbia samples. USGS standard rocks were analyzed using the refined technique developed by the investigators. The results obtained by the investigators agreed with values recommended by the USGS. The concentrations of elements used for standard values in USGS samples are listed below.

Element	SCo-1	BCR-1
	ppm	ppm
As	13.1	0.840
Ba	535	656
Ca	20000	50200
Ce	54.4	53.7
Co	10.6	36.1
Cr	74	16
Cs	7.7	0.93
Eu	1.02	1.92
Fe	34800	95100
Hf	4.7	5.2
K	23600	14200
La	29.2	24.6
Lu	0.370	0.522
Mn	389	1395
Na	6860	24500
Nd	27.3	30.5
Rb	130	44.7
Sb	3.1	0.59
Sc	11.2	31.6
Sm	5.13	6.80
Tb	0.70	1.10
Th	10.9	6.0
U	2.4	1.73
Yb	2.38	3.37
Zn	110	127

A Wiley mill, which grinds with a shearing action was used to prepare the samples. It was equipped with a stainless steel 40-mesh screen in order to reduce Cu contamination. On the basis of tests analyzing concentrations of trace elements in whole fennel seeds and in the same seed after grinding in the Wiley mill, the investigators concluded that for the elements analyzed, no significant contamination of the sample occurred by the Wiley mill except possibly for Mn and Na.

Subsamples of both samples and standards, each weighing about 100 mg, were measured out, dried to a constant weight at 110°C, weighed, and sealed into high purity quartz tubes for irradiation with neutrons. A weighed

length of pure Fe wire (about 60 mg) was wrapped around the portion of each tube containing a sample and secured with Teflon tape to serve as a monitor of the neutron flux. The samples were irradiated for 6 hr in the University of Wisconsin Nuclear Reactor at a neutron flux of $9 \times 10^{12} \text{ n cm}^{-2} \text{ sec}^{-1}$. The samples including the standards were irradiated simultaneously. After irradiation, each sample and standard was transferred to a small (1 cm) plastic bag made by heat sealing two sheets of 1.5 mm thick polyethylene film. The bags were heat sealed, covered with an additional sheet of plastic film, and secured to small cards of posterboard with adhesive tape in preparation for radioassay. Samples mounted in this manner are about 0.1 cm thick and 1 cm² in area and they can be accurately positioned in front of the detector for radioassay.

The samples were radioassayed using high resolution gamma-ray spectroscopy. Two Ge (Li) detectors, each having a nominal volume of 50 cm³ and a resolution for the ⁶⁰Co 1332 KeV line of 2.0 KeV FWHM, were used. The signals from each detector were routed through the appropriate amplifiers and analog to the digital converters of a computer based multichannel analyzer (Tracor Northern Model TN-11). The samples and standards were radioassayed approximately 3, 10, and 40 days after irradiation for about 3,000, 14,000, and 20,000 sec, respectively, for isotopes having intermediate and long half-lives. Gamma rays with energies of <2,048 KeV are recorded at an energy calibration of 1 KeV/channel. After the 40-day radioassay was completed, the samples and standards were removed from the cards and irradiated for 4 min. at a neutron flux of $3 \times 10^{12} \text{ n cm}^{-2} \text{ sec}^{-1}$. The plastic bags containing the samples and standards were rinsed with water and methanol, remounted on cards, and radioassayed for about 700 sec. to determine the elements in count set 0 (Table 3).

The results were calculated using the procedures of Denechaud et al. (1970) except that the peak areas in the gamma-ray spectra and associated decay factors were calculated by an on-line minicomputer using a program developed from their procedures. The concentrations of Cu, Ga, Se, and Sm were measured in standard SO-4 in a separate set of samples by modifications of the investigators' procedures of radiochemical neutron activation analysis (Allen et al. 1970).

Isotope and Gamma Lines--

The isotopes, count sets, and photopeaks selected for analysis are given in Table 2. These choices were based on the relative intensities of the gamma-ray lines in the soils, mutual interferences, accuracy, and minimization of the number of times the samples and standard had to be radioassayed while still maintaining an adequate check on the quality of the radioassays by using multiple gamma-lines for each element within and between count sets. Some comments about interferences in the gamma-ray spectra are given below for selected elements.

Lutetium--The photopeak at 208.3 KeV can have a significant contribution from the 209.7 KeV line of ²³⁹Np. The appropriate correction

TABLE 3. SUMMARY OF INFORMATION PERTAINING TO RADIOASSAY

Nuclide	Half-life	Energies of γ -rays used, KeV	Count set, days	Interferences		
				Isotope or reaction	Half-life	Energy
^{24}Na	15.0h	1368.4, 1732.1	3	$[^{24}\text{Mg}(n,p)^{24}\text{Na}]^b$ $[^{27}\text{Al}(n,\gamma)^{24}\text{Na}]^b$		
^{42}K	12.4h	1524.7	3			
^{47}Ca	4.54d	1297.1	10	$^{152}\text{Eu}^b$	12.7y	1299.2
^{46}Sc	83.9d	889.3	10, 40	$^{110m}\text{Ag}^b$ $^{182}\text{Ta}^a$	255d 115d	884.7 1121.2
^{51}Mn	27.8d	320.1	10, 40	$^{117}\text{Lu}^b$ $[^{54}\text{Fe}(n,\gamma)^{51}\text{Cr}]^b$	6.74d	321.4
^{56}Mn	155m	846.7, 1811.2	0			
^{59}Fe	45.6d	192.2	40			
^{59}Fe	45.6d	1099.3, 1291.5	10, 40			
^{60}Co	5.26y	1173.2, 1332.5	10, 40			
^{64}Cu	12.8h	511.0, 1345.8	3^e	$[\text{e}^+ \text{annihilation}]^a$		
^{65}Zn	243d	1115.5	10, 40	$^{152}\text{Eu}^b$ $^{160}\text{Tb}^b$ $^{46}\text{Sc}^b$	12.7y 72d 83.9d	1112.2 1115.3 1120.5
^{72}Ga	14.12h	629.9, 834.0	3^e			
^{76}As	26.4h	559.1	3			
^{75}Se	120d	136.0	40^e	$^{181}\text{Hf}^b$ $^{131}\text{Ba}^b$ $^{181}\text{Hf}^b$	42.5d 12d 42.5d	133.1 133.7 136.3
^{75}Se	120d	264.7	40			
^{82}Br	35.3h	554.3	3, 10			
^{82}Br	35.3h	619.1	3	$^{131}\text{Ba}^b$	12d	620.2
^{86}Rb	18.7d	1078.8	10, 40	$[^{86}\text{Sr}(n,p)^{85}\text{Rb}]^b$		
^{87m}Sr	169.8m	388.5	0^e	$^{71}\text{Zn}^b$	144s	390.0
$^{110m}\text{Ag}^d$	255d	657.7	40	$^{152}\text{Eu}^a$	12.7y	656.5
^{122}Sb	64.3h	564.1	3, 10	$^{76}\text{As}^b$	26.4h	562.8
^{124}Sb	60.3d	1691.1	40			
^{134}Cs	2.05y	605.0, 797.0	40	$^{124}\text{Sb}^b$	60.3d	602.7

TABLE 3 (continued)

Nuclide	Half-life	Energies of γ -rays used, KeV	Count set, days	Interferences		
				Isotope or reaction	Half-life	Energy
^{131}Ba	12.0d	496.3	10			
^{140}La	40.2h	328.8	10			
^{140}La	40.2h	487.0, 1596.6	3, 10	$^{47}\text{Ca}^b$	4.5d	489.2
^{141}Ce	32.5d	145.5	40			
^{147}Nd	11.1d	531.0	10	$^{153}\text{Sm}^b$	46.8h	531.4
^{153}Sm	46.8d	103.2	3, 10	$^{239}\text{Np}^b$	56h	99.7
				$^{239}\text{Np}^b$	56h	103.7
$^{152\text{m}}\text{Eu}$	9.30h	344.2	0			
^{152}Eu	12.7y	121.8, 779.1, 1408.1	40	$^{75}\text{Se}^b$	120d	121.1
				$^{154}\text{Eu}^c$	16y	123.1
				$^{131}\text{Ba}^b$	12.0d	124.2
^{160}Tb	72.1d	298.6	10, 40	$^{233}\text{Pa}^a$	27d	300.1
^{175}Yb	4.21d	282.6, 396.1	10	$^{239}\text{Np}^b$	56h	285.6
				$^{160}\text{Tb}^b$	72d	392.5
				$^{233}\text{Pa}^b$	27d	398.5
^{169}Yb	31.8d	177.0	40			
^{177}Lu	6.74d	208.3	3, 10	$^{239}\text{Np}^a$	56h	209.7
^{181}Hf	42.5d	133.1	50	^{131}Ba	12.0d	133.7
^{181}Hf	42.5d	482.2	10, 40			
^{182}Ta	115d	1221.3, 1230.9	40			
$^{198}\text{Au}^d$	64.7h	411.8	3, 10	$^{191}\text{Pt}^b$	3.0d	409.6
$^{233}\text{Pa}(\text{Th})$	27.0d	311.9	10, 40	$^{160}\text{Tb}^b$	72.1d	309.6
$^{239}\text{Np}(\text{U})$	56.3h	228.1	3, 10			

^aSerious, similar size peaks not resolved for nearly all samples; corrective measures necessary.

^bPotentially serious, peaks not resolved or marginally resolved, but interfering peak is usually insignificant in most soil samples if sample is radioassayed at optimum time.

^cNot serious, $^{152}\text{Eu}/^{154}\text{Eu}$ ratio is constant for all samples and the half-lives are too long to cause any error.

^dElements present at concentrations below detection limits for most soil samples.

^eRadiochemical separation required prior to radioassay.

can be determined by comparing the peak intensities of ^{239}Np at 209.7 and 228 KeV in a pure sample of U to those observed in the sample.

Bromine, Arsenic, Antimony--Modern Ge (Li) detectors having good resolution and an electronically stable analyzing system are needed to resolve the photopeaks at 554.3, 559.1, and 564.1 KeV, respectively, for these elements. These peaks provide the greatest sensitivity for all three elements, but others are available (Table 2). The 564.1 KeV peak for ^{122}Sb can have a contribution from the 562.8 KeV peak of ^{76}As in samples having high concentration ratios of As to Sb. A correction can be applied to the ^{122}Sb peak using the intensity ratios of the As peaks at 559.1 and 562.8 KeV or the less sensitive ^{124}Sb line at 1691.1 KeV.

Terbium, Thorium--The concentrations of Th are determined by using the 311.9 KeV line of ^{233}Pa which is the daughter of ^{233}Th . The 298.6 KeV line of ^{160}Tb almost always has an interference from the 300.1 KeV line of ^{233}Pa and the 311.9 KeV line of ^{233}Pa can have an interference from the low intensity 309.6 KeV line of ^{160}Tb . The photopeaks can be corrected by using the ratios of the peak intensities determined from reference samples but successive approximations must be used in those samples where the isotopes mutually interfere.

Hafnium--In most soils, the 133.7 KeV line of 12-day ^{131}Ba interferes with the 133.1 KeV line of ^{181}Hf for samples radioassayed before about 40 days after irradiation. The 136.0 KeV peak from ^{75}Se can produce uncertainty in the placement of the baseline.

Chromium--Samples having abnormally high concentration ratios of Fe to Cr can yield high results for Cr because of the interfering reaction of Fe with epithermal neutrons [$^{54}_{26}\text{Fe}(n,\alpha)^{51}_{24}\text{Cr}$]. The 321.4 KeV line of 6.74 day ^{177}Lu can interfere with the 320.1 KeV line of ^{51}Cr in the 10-day count set.

Zinc--The 1115.5 line of ^{65}Zn is between the 1112.2 KeV line of ^{152}Eu and the usually intense 1120.5 KeV line of ^{46}Sc . Satisfactory results for Zn can be obtained from spectra obtained by counting systems having good resolution, especially if only the top three channels of the Zn peak are used.

Supporting Documents

Koons, R. D., and P. A. Helmke. Neutron activation analysis of standard soils. Available in: Representative Papers From a Study of the Impact of Coal-Fired Power Plants on the Environment. Institute for Environmental Studies, University of Wisconsin-Madison.

Trace Elements. In: Documentation on environmental change related to the Columbia Electric Generating Station. Institute for Environmental Studies, Reports 46, 58, 92. University of Wisconsin-Madison.

DATA SET C4B1: THE CONCENTRATION OF TRACE ELEMENTS IN OAK LEAVES NEAR THE COLUMBIA GENERATING STATION (1973-76)

Data Summary

Investigators--

W. P. Robarge, R. P. Koone, P. A. Helmke.

Abstract--

To monitor the environmental effects of emissions from the Columbia Generating Station on vegetation, oak leaves from four sites around the power plant were collected and analyzed for trace elements. The sites were located 0.8 to 16 miles from the stack in all directions. Samples were collected monthly during two growing seasons (1975-76) and irregularly during 1973 and 1974. The samples were analyzed for elemental concentrations by nondestructive neutron activation analysis (Koons and Helmke 1978) including: Ag, As, Au, Ba, Br, Ca, Ce, Co, Cr, Cs, Eu, Hf, Fe, K, La, Lu, Mn, N, Na, Nd, Rb, P, S, Sb, Sc, Se, Sm, Tb, U, Yb, and Zn. For Cd, Cu, Hg and sometimes As the radiochemical separation procedure (Allen et al. 1970) was used.

Dates of Research--

1973-1976.

Data Form

Computer file containing 112 units with 10 card-images/unit.

Data Format

Field Description--

Card #1

<u>Column</u>	<u>Format</u>	<u>Description</u>
1	II	Site 1=D12A, 2=FW36A, 3=P34A, 4=W5B
3-4	I2	Sample number within site
6-7	I2	Total number of samples at a given site
9-10	I2	Month collected
11-12	I2	Day collected
13-14	I2	Leaf treatment: 1=washed, 2=unwashed
18	I1	Species: 1= <i>Q. velutina</i> , 2= <i>Q. alba</i>
20	F7.5	Sample wt (gm)
80	I1	Image sequence, 1 for card #1

Card #2

1	I1	Indicator code for Ag ⁵
3-10	F8.4	Ag concentration (ppm)
11-18	F8.4	Ag uncertainty term
20	I1	Indicator code for As
22-29	F8.4	As concentration (ppm)
30-37	F8.4	As uncertainty term
39	I1	Indicator code for Au
41-48	F8.4	Au concentration (ppm)
49-56	F8.4	Au uncertainty term
58	I1	Indicator code for Ba
60-67	F8.4	Ba concentration (ppm)
68-75	F8.4	Ba uncertainty term
80	I1	Image sequence, 1 for data card #1

Card #3

1	I1	Indicator code for Br
3-11	F8.4	Br concentration (ppm)
11-18	F8.4	Br uncertainty term
20	I1	Indicator code for Ca
22-29	F8.4	Ca concentration (%)
30-37	F8.4	Ca uncertainty term
39	I1	Indicator code for Cd
41-48	F8.4	Cd concentration (ppm)
49-56	F8.4	Cd uncertainty term
58	I1	Indicator code for Ce
60-67	F8.4	Ce concentration (ppm)
68-75	F8.4	Ce uncertainty term
80	I1	Image sequence, 2 for data card #2

Card #4

1	I1	Indicator CDDE for Cl
3-10	F8.4	Cl concentration (ppm)
11-18	F8.4	Ba uncertainty term
20	I1	Indicator code for Co
22-29	F8.4	Co concentration (ppm)
30-37	F8.4	Co uncertainty term
39	I1	Indicator code for Cr
41-48	F8.4	Cr concentration (ppm)
49-56	F8.4	Cr uncertainty term
58	I1	Indicator code for Cs
60-67	F8.4	Cs concentration (ppm)
68-75	F8.4	Cs uncertainty term
80	I1	Image sequence, 3 for data card #3

⁵1 Indicates actual value is less than following entry and uncertainty is zero. 0 Indicates following entry is exact with given uncertainty.

Card #5

1	I1	Indicator code for Cu
3-10	F8.4	Cu concentration (ppm)
11-18	F8.4	Cu uncertainty term
20	I1	Indicator code for Eu
22-29	F8.4	Eu concentration (ppm)
30-37	F8.4	Eu uncertainty term
39	I1	Indicator code for Fe
41-48	F8.4	Fe concentration (ppm)
49-56	F8.4	Fe uncertainty term
58	I1	Indicator code for Hf
60-67	F8.4	Hf concentration (ppm)
68-75	F8.4	Hf uncertainty term
80	I1	Image sequence 4 for data card #4

Card #6

1	I1	Indicator code for Hg
3-10	F8.4	Hg concentration (ppm)
11-18	F8.4	Hg uncertainty term
20	I1	Indicator code for K
22-29	F8.4	K concentration (%)
30-37	F8.4	K uncertainty term
39	I1	Indicator code for La
41-48	F8.4	La concentration (ppm)
49-56	F8.4	La uncertainty term
58	I1	Indicator code for Lu
60-67	F8.4	Lu concentration (ppm)
68-75	F8.4	Lu uncertainty term
80	I1	Image sequence , 5 for data card #5

Card #7

1	I1	Indicator code for Mn
3-10	F8.4	Mn concentration (ppm)
11-18	F8.4	Mn uncertainty term
20	I1	Indicator code for N
22-29	F8.4	N concentration (%)
30-37	F8.4	N uncertainty term
39	I1	Indicator code for Na
41-48	F8.4	Na concentration (ppm)
49-56	F8.4	Na uncertainty term
58	I1	Indicator code for Nd
60-67	F8.4	Nd concentration (ppm)
68-75	F8.4	Nd uncertainty term
80	I1	Image sequence, 6 for data card #6

Card #8

1	I1	Indicator code for P
3-10	F8.4	P concentration (%)

11-18	F8.4	P uncertainty term
20	I1	Indicator code for Rb
22-29	F8.4	Rb concentration (ppm)
30-37	F8.4	Rb uncertainty term
39	I1	Indicator code for S
41-48	F8.4	S concentration (%)
49-56	F8.4	S uncertainty term
58	I1	Indicator code for Sb
60-67	F8.4	Sb concentration (ppm)
68-75	F8.4	Sb uncertainty term
80	I1	Image sequence, 7 for data card #7

Card #9

1	I1	Indicator code for Sc
3-10	F8.4	Sc concentration (ppm)
11-18	F8.4	Sc uncertainty term
20	I1	Indicator code for Se
22-29	F8.4	Se concentration (ppm)
30-37	F8.4	Se uncertainty term
39	I1	Indicator code for Sm
41-48	F8.4	Sm concentration (ppm)
49-56	F8.4	Sm uncertainty term
58	I1	Indicator code for Tb
60-67	F8.4	Tb concentration (ppm)
68-75	F8.4	Tb uncertainty term
80	I1	Image sequence, 8 for data card #8

Card #10

1	I1	Indicator code for Th
3-10	F8.4	Th concentration (ppm)
11-18	F8.4	Th uncertainty term
20	I1	Indicator code for U
22-29	F8.4	U concentration (ppm)
30-37	F8.4	U uncertainty term
39	I1	Indicator code for Yb
41-48	F8.4	Yb concentration (ppm)
49-56	F8.4	Yb uncertainty term
58	I1	Indicator code for Zn
60-67	F8.4	Zn concentration (ppm)
68-75	F8.4	Zn uncertainty term
80	I1	Image sequence, 9 for data card #9

Data Sample

The sample presented here is 2 units, 36 and 37, of the 112 records included in data set C4B1.

2	01	34	999999	1	2	0.20057													
0	999		000		0	999	000		0	999	000		0	112.		2.			1
0		5.6		0.1	0		1.17	0.12	0	999	000		0		0.38		0.05		2
0	999		000		0		0.028	0.004	0		0.30	0.05	0		0.24		0.01		3
0	999		000		0		0.010	0.002	0	88.		4.	0		0.014		0.004		4
0	999		000		0		0.88	0.01	0		0.26	0.01	0	999		000		5	
0	2260.		50.		0		2.24	997	0	10.4		0.5	0	999		000		6	
0		0.2510	997		0		36.	1.	0		0.1625	997	0		0.021		0.003		7
0		0.0128	0.0005		0	999		000	0		0.034	0.003	0	999		000		8	
0		0.015	0.004		0	999		000	0		0.009	0.003	0		15.4		0.4		9
2	02	34	999999	1	2	0.24804													
0	999		000		0	999	000		0	999	000		0	109.		3.			1
0		5.7		0.2	0		1.00	0.02	0	999	000		0		0.32		0.04		2
0	999		000		0		0.032	0.004	0		0.29	0.04	0		0.244		0.007		3
0	999		000		0		0.010	0.002	0	79.		5.	0		0.020		0.006		4
0	999		000		0		0.79	0.01	0		0.22	0.02	0	999		000		5	
0	2030.		40.		0		2.33	997	0		8.6	0.6	0	999		000		6	
0		0.1899	997		0		33.	1.	0		0.1585	997	0		0.020		0.003		7
0		0.0101	0.0004		0	999		000	0		0.030	0.003	0	999		000		8	
0	999		000		0	999		000	0		0.009	0.002	0		14.0		0.4		9

Objectives--

Sampling Sites--

Sampling Procedures--

To remove surface contamination, the leaf samples were washed three times by a gentle 30-sec agitation with deionized water shortly after collection.

These preparatory procedures were selected after preliminary study was conducted to determine an effective method for removing surface contamination that would not at the same time leach trace elements out of

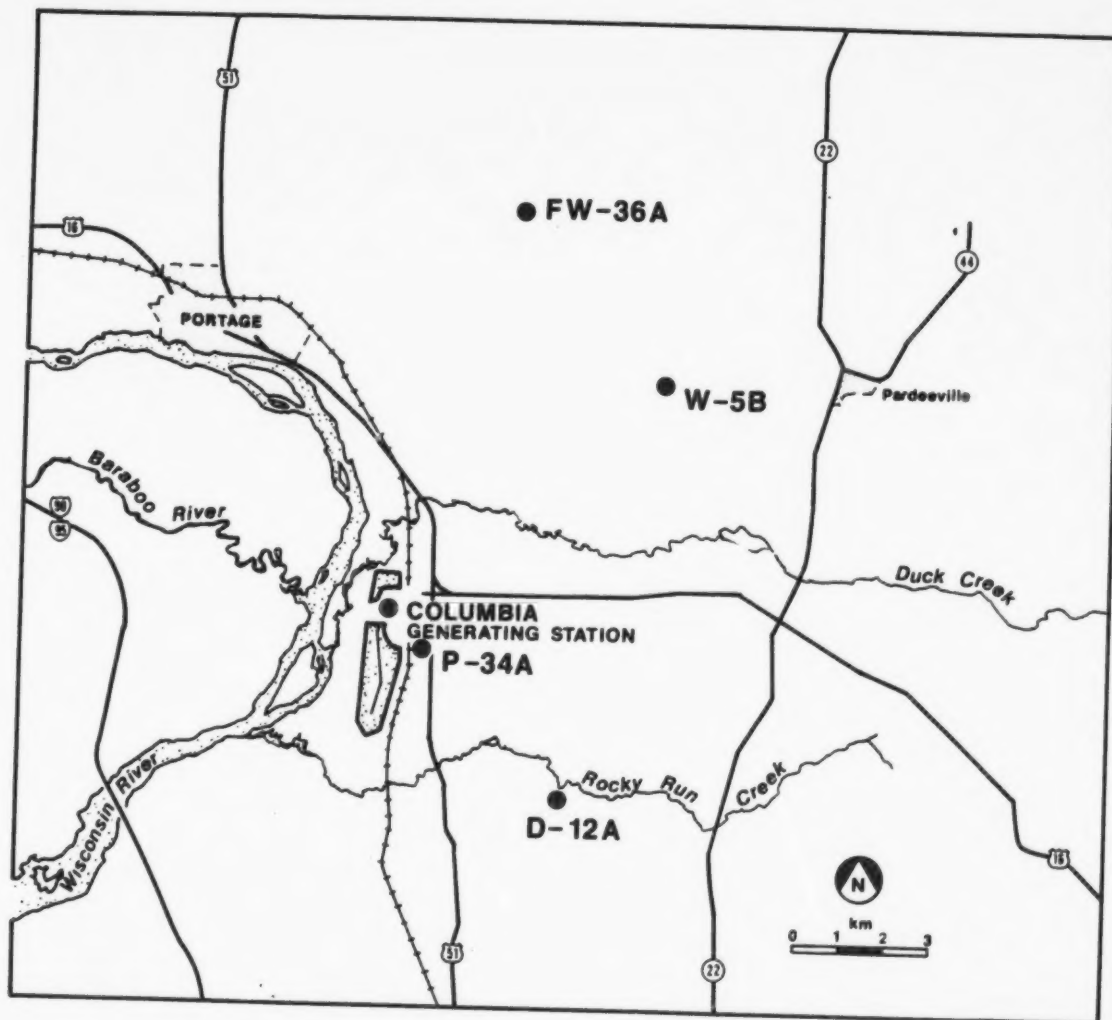


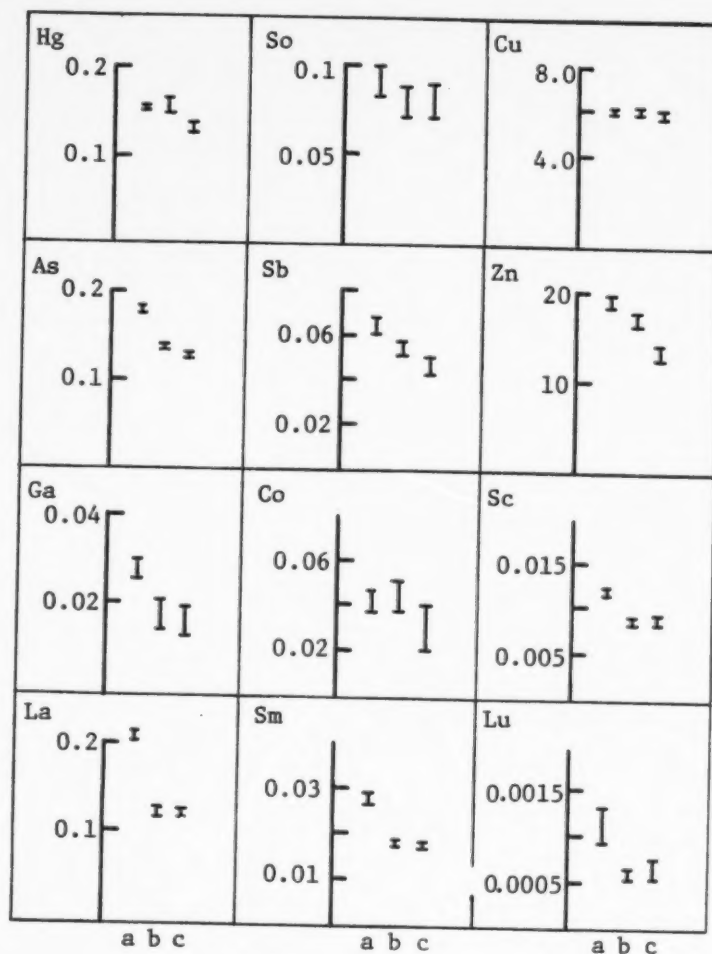
Figure 8. Locations of sampling sites for oak leaves.

the plant material itself. In this preliminary study, 60 fresh leaves from a single white oak (*Quercus alba*) were collected on the University of Wisconsin-Madison campus. The leaves were divided randomly into three groups. The first group was not washed; the second was washed three times (30 sec each with distilled water); and the third was washed once with 0.1 N HCl and twice with distilled water. The samples were air-dried and ground by hand in a mortar and pestle to pass a 1/16 inch mesh nylon sieve. A portion of each sample was analyzed by neutron activation with radiochemical separations to obtain concentrations of As, Co, Cu, Ga, Hg, La, Lu, Sb, Sc, Se, Sm and Zn (Figure 9). The data show that the concentrations of Cu, an essential element, were not appreciably affected by washing, while those of such elements as Ga, Sc, La, Lu, and Sm, which are present at fairly high concentrations in the earth's crust (i.e. dust) but which have no known biological function, were reduced 20 to 40% by washing. No discernible difference existed in the concentrations of these elements between washing with water and washing with HCl and water. Other essential elements displayed different patterns. The concentration of Co was unaffected by washing with water, but it was possibly lowered slightly by an acid wash. The concentration of Zn was lowered by a water wash, but even more by acid washing. Selenium (toxic at high levels but essential in trace amounts) showed no significant decrease in concentrations with washing. Of the potentially toxic elements, the concentrations of As and Sb were reduced by a water wash, but the reduction was slightly greater with an acid wash. The concentration of Hg appeared unaffected by washing with water, but it was lowered slightly by an acid wash.

"Indicators" of surface contamination by inorganic materials, elements such as Ga, Sc, La, Sm, and Lu, all showed that washing with water is just as effective as washing with 0.1 N HCl in removing contamination. The greater reduction in the concentrations of Hg, Zn, Sb, and possibly As and Co when leaves were washed with acid, compared to water, suggests that this further reduction might be the result of leaching of these elements from the leaves.

As a result of this preliminary test, the procedure of three consecutive washings with water, described above, was adopted. After washing, the leaves were air-dried for several days and dried at 40°C for 24 hr. The samples were ground in a Wiley mill equipped with a 40-mesh stainless steel screen. On the basis of tests analyzing concentrations of trace elements in whole fennel seeds and in the same seeds after grinding in the Wiley mill, the investigators concluded that for the elements analyzed, no significant contamination of the sample occurred by the Wiley mill except possibly for Mn and Na. The samples were stored subsequently in acid-washed glass bottles with a Telfon-lined lid.

Analysis was conducted by a combination of instrumental neutron-activation (INAA--no chemical separation before gamma-ray spectrometry) and radio-chemical neutron spectrometry. Several elements that are of interest require this chemical technique for accurate analysis because of either low concentrations or interferences.



a = unwashed
 b = washed three times with distilled water
 c = washed once with 0.1N HCl, then twice with distilled water

Figure 9. Trace element concentrations in white oak (*Quercus alba*) leaves.

Investigators--

This study was conducted by Wayne P. Robarge and Robert P. Koons. At the time of the study, they were working toward Ph.D. degrees in Soil Science at the University of Wisconsin-Madison. The study was conducted under the supervision of assistant professor Philip Helmke.

Supporting Documents

Helmke, P. A., and P. Page. Fly ash deposition. In: Representative Papers from a Study of the Impact of Coal-Fired Power Plants on the Environment. Institute for Environmental Studies, University of Wisconsin-Madison, Madison, Wisconsin.

Trace elements. In: Documentation on environmental change related to the Columbia Electric Generating Station. Institute for Environmental Studies, Reports 46, 58, 62, 66, 69, 82, 92. University of Wisconsin-Madison, Madison, Wisconsin.

DATA SET C4C1: CONCENTRATION OF TRACE ELEMENTS IN AQUATIC ORGANISMS COLLECTED NEAR THE COLUMBIA GENERATING STATION (1974-76)

Data Summary

Investigators--

M. B. Schoenfield and P. A. Helmke.

Abstract--

This study determined changes in trace-element concentrations of aquatic arthropods as indicators of environmental quality. Samples were collected from 1974 through 1976 in the aquatic system around the Columbia Generating Station. The samples were analyzed by nondestructive neutron activation analysis (Koons and Helmke 1978) for the following elements: As, Ba, Br, Ca, Ce, Co, Cr, Cs, Eu, Hf, Fe, K, La, Lu, Mn, Rb, Sb, Sc, Se, Sm, Tb, Th, Yb, and Zn. For Cd, Cu, Hg and sometimes As a radiochemical separation procedure (Allen et al. 1970) was used.

Dates of Research--

1974-1976.

Data Form--

Computer file containing 87 units with 8 card-images per unit.

Data Format

Field Description--

Card #1

<u>Column</u>	<u>Format</u>	<u>Description</u>
1-2	I2	ID number of sample
4	I1	Class: 1=Crustacea, 2=Insecta
6	I1	Order: 1=Amphipoda, 2=Isopoda, 3=Coleoptera, 4=Hemiptera, 5=Odonata
8	I1	Family: 1=Gammaridae, 2=Talitridae, 3=Asellidae, 4=Gyrinidae, 5=Corixidae, 6=Aeshnidae, 7=Corduliidae, 8=Libellulidae
9-10	I2	Genus: 01=Gammarus, 02=Hyalomma azteca, 03=Asellus racovitzai, 04=Dineutus, 05=Hesperocopixa rocorixa, 06=Sigara, 07=Anax, 08=Tetragoneuria, 09=Libellula, 10=Sympetrum
12-13	I2	Sample number
15-16	I2	Date collected: month
17-18	I2	day
19-20	I2	year
22-23	I2	Site collected: 01=A, 02=B, 03=BC, 04=C, 05=D, 06=E, 07=MD, 08=RRS, 09=RRL, 10=RRU
25-31	F7.5	Sample mass in grams
32-34	I3	Number of organisms
36-40	F5.2	Mean size organism (Mg)
80	I1	Card #1

Card #2

1-2	I2	I.D. number of sample
4	I1	Indicator code for As ⁶
6-13	F8.4	As concentration (ppm)
14-21	F8.4	As analytical uncertainty term
23	I1	Indicator code for Ba
25-32	F8.4	Ba concentration (ppm)
33-40	F8.4	Ba analytical uncertainty term
42	I1	Indicator code for Br
44-51	F8.4	Br concentration (ppm)
52-59	F8.4	Br analytical uncertainty term
61	I1	Indicator code for Ca
63-70	F8.4	Ca concentration (ppm)
71-78	F8.4	Ca analytical uncertainty term
80	I1	Card #2

⁶0 indicates that following entry is correct measurement; 1 indicates that following entry is less than entry; analytical uncertainty term in latter case will be entered as zero.

Card #3

1-2	I2	I.D. number of sample
4	I1	Indicator code for Ce
5-12	F8.4	Ce concentration (ppm)
13-20	F8.4	Ce analytical uncertainty term
22	I1	Indicator code for Co
23-30	F8.4	Co concentration (ppm)
31-38	F8.4	Co analytical uncertainty term
40	I1	Indicator code for Cr
41-48	F8.4	Cr concentration (ppm)
49-56	F8.4	Cr analytical uncertainty term
58	I1	Indicator code for Cs
59-66	F8.4	Cs concentration (ppm)
67-74	F8.4	Cs analytical uncertainty term
80	I1	Card #3

Card #4

1-2	I2	I.D. number of sample
4	I1	Indicator code for Cu
5-12	F8.4	Cu concentration (ppm)
13-20	F8.4	Cu analytical uncertainty term
22	I1	Indicator code for Eu
23-30	F8.4	Eu concentration (ppm)
31-38	F8.4	Eu analytical uncertainty term
40	I1	Indicator code for Hf
41-48	F8.4	Hf concentration (ppm)
49-56	F8.4	Hf analytical uncertainty term
58	I1	Indicator code for Hg
59-66	F8.4	Hg concentration (ppm)
67-74	F8.4	Hg analytical uncertainty term
80	I1	Card #4

Card #5

1-2	I2	I.D. number of sample
4	I1	Indicator code for Fe
5-12	F8.4	Fe concentration (ppm)
13-20	F8.4	Fe analytical uncertainty term
22	I1	Indicator code for K
23-30	F8.4	K concentration (ppm)
31-38	F8.4	K analytical uncertainty term
40	I1	Indicator code for La
41-48	F8.4	La concentration (ppm)
49-56	F8.4	La analytical uncertainty term
58	I1	Indicator code for Lu
59-66	F8.4	Lu concentration (ppm)
67-74	F8.4	Lu analytical uncertainty term
80	I1	Card #5

Card #6

1-2	I2	I.D. number of sample
4	I1	Indicator code for Mn
5-12	F8.4	Mn concentration (ppm)
13-20	F8.4	Mn analytical uncertainty term
22	I1	Indicator code for Na
32-30	F8.4	Na concentration (ppm)
31-38	F8.4	Na analytical uncertainty term
40	I1	Indicator code for Rb
41-48	F8.4	Rb concentration (ppm)
49-56	F8.4	Rb analytical uncertainty term
58	I1	Indicator code for Sb
59-66	F8.4	Sb concentration (ppm)
67-74	F8.4	Sb analytical uncertainty term
80	I1	Card #6

Card #7

1-2	I2	I.D. number of sample
4	I1	Indicator code for Sc
5-12	F8.4	Sc concentration (ppm)
13-20	F8.4	Sc analytical uncertainty term
22	I1	Indicator code for Se
23-30	F8.4	Se concentration (ppm)
31-38	F8.4	Se analytical uncertainty term
40	I1	Indicator code for Sm
41-48	F8.4	Sm concentration (ppm)
49-56	F8.4	Sm analytical uncertainty term
58	I1	Indicator code for Tb
59-66	F8.4	Tb concentration (ppm)
67-74	F8.4	Tb analytical uncertainty term
80	I1	Card #7

Card #8

1-2	I2	I.D. number of sample
4	I1	Indicator code for Th
5-12	F8.4	Th concentration (ppm)
13-20	F8.4	Th analytical uncertainty term
22	I1	Indicator code for Yb
23-30	F8.4	Yb concentration (ppm)
31-38	F8.4	Yb analytical uncertainty term
40	I1	Indicator code for Zn
41-48	F8.4	Zn concentration (ppm)
49-56	F8.4	Zn analytical uncertainty term
58	I1	Indicator code for U
59-66	F8.4	U concentration (ppm)
67-74	F8.4	U analytical uncertainty term

Data Sample

The sample presented here is 2 units, 62 and 63, of the 87 records included in data set C4C1.

```

1234567890123456789012345678901234567890123456789012345678901234567890
62 2 5 809 21 100776 10 .04442 1 44.42 1
62 1 2.0 000 0 21. 5. 0 103. 9. 0 14000 2000 2
62 0 1.3 0.1 0 0.63 0.02 0 5.0 0.3 0 0.08 0.01 3
62 0 999 000 0 0.034 0.003 0 0.20 0.03 0 999 000 4
62 0 1400 30 0 11500 700 0 0.84 0.04 0 0.013 0.002 5
62 0 100. 2. 0 11900 200 0 7.0 0.7 1 0.03 000 6
62 0 0.229 0.005 0 2.3 0.3 0 0.07 0.01 0 0.024 0.005 7
62 0 0.22 0.02 0 0.07 0.01 0 109. 2. 0 999 000 8
63 2 5 809 22 100776 03 .05969 1 59.69 1
63 1 2.7 000 0 32. 6. 0 110. 10. 0 11000 1000 2
63 0 1.2 0.1 0 0.38 0.01 0 13.8 0.3 0 0.10 0.01 3
63 0 999 000 0 0.026 0.002 0 0.45 0.04 0 999 000 4
63 0 1570 30 0 11000 1000 0 0.68 0.03 0 0.027 0.002 5
63 0 69. 1. 0 8800 200 0 10. 1. 0 0.24 0.03 6
63 0 0.170 0.003 0 3.5 0.5 0 0.097 0.005 0 0.020 0.003 7
63 0 0.17 0.02 0 0.17 0.03 0 119. 2. 0 999 000 8

```

QUALITY ASSURANCE

Objectives--

This study shows the feasibility of using trace element composition of aquatic amphibians and arthropods as indicators of environmental quality. The major objective of the study was to develop techniques for sampling, analyzing and interpreting trace element levels in the biotic component of aquatic ecosystems. This study also provides baseline data on the elemental composition of a diverse group of aquatic arthropods. From this data, limited conclusions can be drawn about some variables which seem to affect steady state element concentration in aquatic organisms exposed to ash effluent from a coal-fired power plant.

Sampling Sites--

The study was conducted in the vicinity of the Columbia Generating Station, Columbia County, Wisconsin. The sampling sites (Figure 10) vary in distance from the ashpit basin so that the range of influence of the ash effluent could be assessed.

The mint drain (site MD) is a channelized stream about 3.5 km long that drains an area of about 7.8 km² composed primarily of mint fields and wetlands. Samples were taken from the mint drain for use as a control.

The sampling site closest to the ashpit basin is located just downstream from the confluence of the mint drain and the ashpit drain. This

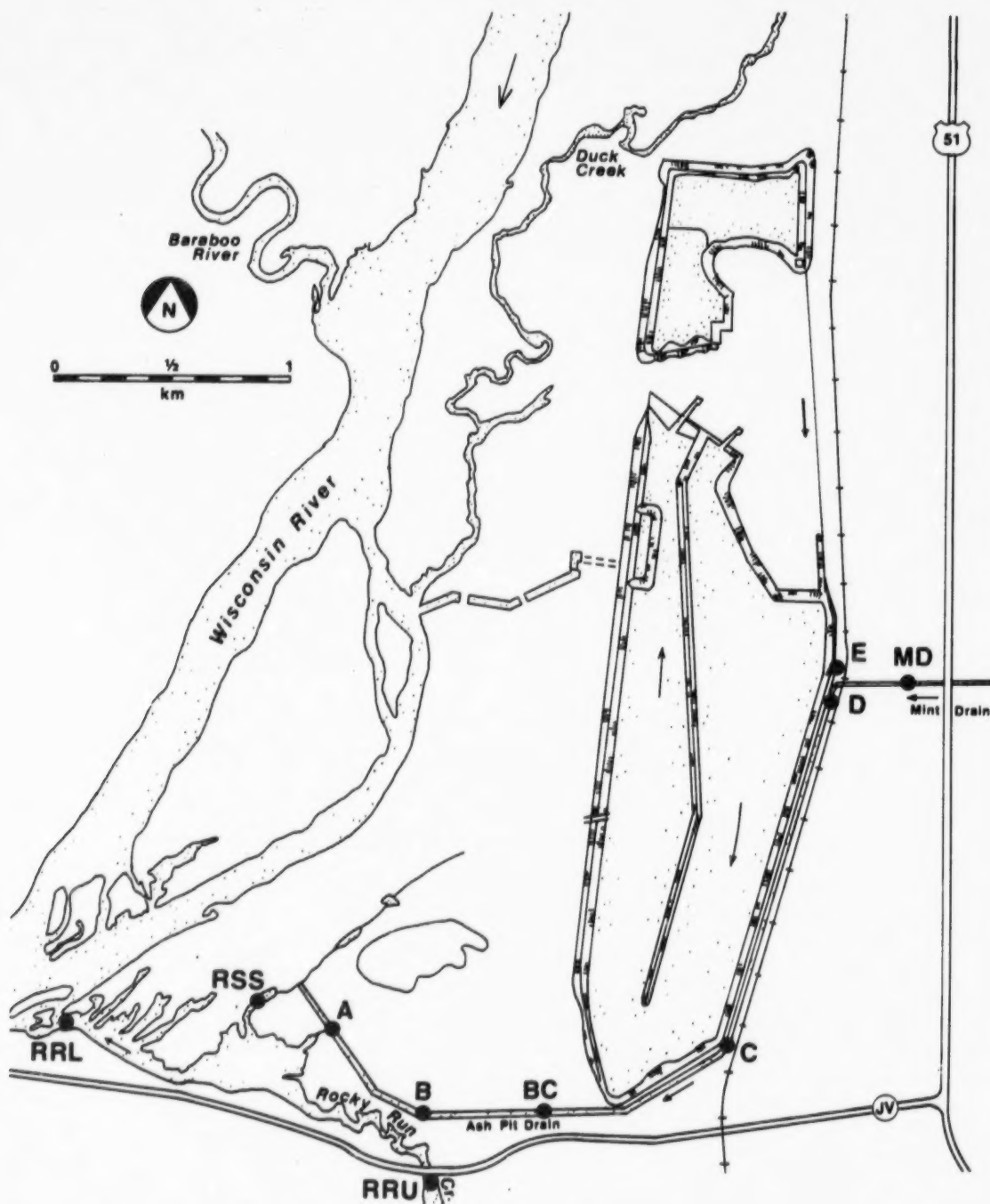


Figure 10. Sampling sites for the collection of aquatic organisms.

site has been labeled site D. Sampling sites C, BC, B, and A were established 2.1, 2.9, 3.4, and 4.0 km downstream from site D. About 250 m downstream from site A, the ashpit drain joins a slough of Rocky Run Creek. A few samples were collected in the slough downstream from the confluence of the ashpit drain and Rocky Run Creek to explore possible influences of the effluent from the ashpit drain on organisms in Rocky Run Creek. In addition, some samples were collected at two other sites: Rocky Run Lower (RRL), to measure further the effect of the ashpit drain; and Rocky Run Upper (RRU), for use as a control.

Sample Collection--

Samples were collected from 1974 through 1978. Most organisms were collected with a nylon dip net. The only metal part of the dip net was a brass bracket joining the net to an extension pole; no organisms came into contact with brass. To collect organisms, the dip net was dragged through sections of the bottom that seemed likely to provide good habitat for benthic invertebrates. The contents of the dip net were dumped on the stream bank. Specimens were removed from the sediments with stainless steel forceps and placed into plastic or glass vials, or plastic bags. Water from the collection site was added to the sample containers.

Artificial substrate samplers also were used to collect organisms. The samplers consisted of nylon-mesh, produce bags containing limestone rock fragments 3 to 7 cm in diameter. The samplers were allowed to rest gently on the stream bottom. Air-filled plastic jugs were used as floats to prevent the samplers from sinking where the sediments were soft. Nylon dish-scouring pads, tied to the hemp or nylon twine that connected the floats to the stone samplers, served as additional artificial substrates. The substrates were usually colonized by organisms within 4 weeks. At the time of collection, the rock substrates were removed from the water and placed in a plastic tub. The net was slashed to free the rocks for examination. Specimens were captured and stored in the same manner as the specimens collected with the dip net. The nylon dish scouring pads were placed directly into plastic bags containing site water and examined for organisms in the laboratory. All samples were stored in an ice-filled cooler until ready for analysis.

Prior to analysis, all organisms were washed in the laboratory by allowing the organisms to move about in containers of distilled-deionized water. Three successive baths lasting about 5 min. each were normally used. The washed specimens were blotted dry with paper toweling, counted and placed into clean, pre-weighed vials. The vials were weighed to obtain estimates of wet ("fresh") weight. The samples were then stored in a freezer. Most of the organisms remained alive until the time of freezing. Prior to analysis, the frozen samples were lyophilized to constant mass in a pyrex freeze dryer with liquid N and dry ice cold traps.

In order to estimate the effects of ingested material on the measured concentrations of elements in the samples of organisms, samples of *Asellus racovitsai* were held in baths of distilled-deionized water at 8 to 10°C for up to 1 week to allow the organisms to empty their guts. The water was

changed daily. The material eliminated by the organisms was collected by filtering and dried at 60°C in preparation for analysis. Ingested material was easily visible in the organisms when they were examined in bright light. Specimens were examined on a daily basis and those with empty guts were removed, washed, weighed, and frozen.

Multielemental Analysis Procedures--

For nondestructive neutron activation, the standards and freeze-dried samples, weighing between 30 and 150 mg, were placed into pre-weighed, high purity quartz tubing, heat-sealed at one end. The sample and tubing were re-weighed, and the tube was heat-sealed at the other end. United States Geological Survey SCo-1 (Cody Shale) and National Bureau of Standards SRM 1577 (Bovine Liver) were used as standards. The samples and standards were irradiated in the University of Wisconsin Nuclear Reactor at a neutron flux of approximately 9.9×10^{12} neutrons/cm²/sec for 6 hr. The neutron flux received by each standard was compared to the flux received by each sample through Fe wire flux monitors wrapped around each tube. Flux corrections were calculated by comparing the specific gamma-ray activity for standard and sample Fe wire monitors. Following activation, samples and standards were removed quantitatively from the tubes and sealed into polyethylene pouches. Once in the pouches, the samples were pressed firmly by hand to flatten them. The pouches were taped to 6.4 x 8.4 cm posterboard counting cards for radioassay. Small, flat samples are necessary to minimize counting error due to geometry differences between samples and standards. As shown in Table 2, each standard and sample was radioassayed four times.

One to 3 months after the third radioassay, the samples and standards were re-irradiated in the reactor at a neutron flux of approximately 9.9×10^{12} neutrons/cm²/sec for 2 min. The pouches containing the samples and standards were removed from the posterboard, placed into groups of three to four samples surrounding the standard, and sealed into an additional polyethylene pouch for activation. After re-irradiation, the samples and standards were again taped to the posterboard for Mn radioassay.

The counting schedule was designed to minimize interferences in the gamma-ray spectrum that would detract from elements whose activity is desired. Concurrently, this counting regime allows for maximum cross correlation of elements between counting sets and between energies within a counting set to minimize random errors.

The area of each photopeak was determined by a Tracor Northern minicomputer by adapting the manual method reported by Denechaud et al. (1970) to a program developed by Helmke.

Uncertainties stemming from counting statistics are assigned to the concentration determined for each element. Element concentrations are usually determined by more than one gamma-ray energy and/or by the same gamma-ray counted after different decay intervals. When the counting uncertainties associated with the several peak determinations agree within one standard deviation, the peak value used to calculate the reported

concentration was found by calculating the mean of the individual peak values. In this case, the lowest counting uncertainty (of the two or more separate peak values used to calculate the mean) is the number that was used in reporting the analytical error for the reported concentration. When the separate peak determinations do not agree within one standard deviation, however, the larger uncertainty of the separate peak determinations is used to designate the analytical uncertainty of the reported concentration. When more than two peak values are available for an element and one value differs significantly from the others, the odd value is discarded and the mean peak value is calculated by finding the mean of the remaining values. Instances of odd peak values can usually be attributed to gamma-ray interferences of known origin. In some instances, manual data point calculations by the method of Denechaud et al. (1970) clarified erroneous peak values.

In assigning the counting uncertainty as the analytical error for the reported concentrations, it is assumed that this error is by far the most important source of analytical uncertainty. Uncertainties arising from sample weighing, transfer from quartz tubes to polyethylene pouches, and flux corrections probably do not contribute significantly ($<2.07\%$) to total uncertainty. Where final counting uncertainties on the mean peak are $<2.0\%$, analytical uncertainties of 2.0% were arbitrarily assigned to final values for element concentrations.

Procedures for Radiochemical Separations--

The concentrations of Cd, Cu, Hg and sometimes As and Sb were too low to be analyzed by nondestructive neutron activation analysis due to the presence of interfering sources of gamma-rays. Chemical separations were used to remove elements causing interferences. With few exceptions, the separations were performed using the techniques developed by Henzler et al. (1974).

Due to the difficulty of collecting samples, and so that a clearer understanding of the variability in the composition of the organisms could be ascertained, the samples used in nondestructive analyses also were used in the radiochemical separations. Three to 6 months after the initial activation, and more than 7 days after the 2-min. activation for the Mn assay, the samples were reirradiated for 3 hr. Immediately after activation, the samples were dissolved by refluxing in an acid solution containing appropriate carriers. The method of Allen et al. (1970) was used in the preparation of standards and carriers. These standards were checked by analyzing the bovine liver standard along with the sample unknowns.

Investigators--

Most of the research was conducted by M. Schoenfield. At the time of this research he was working toward an M.S. degree in Soil Science at the U.W.-Madison and is part of his M.S. thesis. The work was supervised by Assistant Professor P. Helmke, Department of Soil Science, University of Wisconsin-Madison.

Supporting Documents

Schoenfield, Myles. 1977. Trace elements in aquatic organisms from the environment of a coal burning generating station. M.S. Thesis, University of Wisconsin-Madison, Madison, Wisconsin.

Trace Elements. In: Documentation on environmental change related to the Columbia Electric Generating Station. Institute for Environmental Studies, Reports 58, 62, 66, 69, 82, 92. University of Wisconsin-Madison.

DATA SET C4C2: TRACE ELEMENT CONTAMINATION IN AMPHIBIANS FROM THE ASHPIT DRAIN OF THE COLUMBIA GENERATING STATION (1974-76)

Data Summary

Investigators--

M. B. Schoenfield and P. A. Helmke.

Abstract--

This study examined changes in trace-element concentrations in aquatic amphibians (frogs) as indicators of environmental quality. Samples were collected adjacent to or in the ashpit drain of the Columbia Generating Station on 8 Nov. 1974 and 13 Aug. 1975. The samples were analyzed by nondestructive neutron activation analysis (Koons and Helmke 1978) for As, Ba, Br, Ca, Ce, Co, Cr, Cs, Eu, Hf, Fe, K, La, Lu, Mn, Na, Rb, Sb, Sc, Se, Sm, Tb, Th, Yb, and Zn. For Cd, Cu, Hg and sometimes As, a radiochemical separation procedure (Allen et al. 1970) was used.

Dates of Research--

1974-1976.

Data Form--

Computer file containing 25 units with one card-image/unit.

Data Format

Field Description--

Card #1

<u>Column</u>	<u>Format</u>	<u>Description</u>
1-2	I2	Number of sample
4	I1	Type of sample: 1=liver, 2=muscle, 3=skin
6-8	I3	I.D. number of frog used
10-12	I3	% of sample from first frog

14-16	I3	I.D. number of second frog used.
18-19	I2	% of sample from sample frog
21-23	I3	I.D. number of third frog used
25-26	I2	% of sample from third frog
		Error--997 if only one or two frogs are used
28	I1	Site; A=1, B=2, C=3, D=4
30-33	I4	Date (month, year)
42	I1	Indicator code: 0 - =, 1 - <
44-51	F8.4	As concentration (ppm)
52-59	F8.4	As analytical uncertainty
61	F8.4	Indicator code for Ba
63-70	F8.4	Ba concentration (ppm)
71-78	F8.4	Ba analytical uncertainty
80	I1	Image sequence, 1 for Card #1

Card #2

1-2	I2	Number of sample
4	I1	Indicator code for Br
6-12	F8.4	Br concentration (ppm)
14-21	F8.4	Br analytical uncertainty
23	I1	Indicator code for Ca
25-32	F8.4	Ca concentration (ppm)
33-40	F8.4	Ca analytical uncertainty
42	I1	Indicator code for Co
44-51	F8.4	Co concentration (ppm)
52-59	F8.4	Co analytical uncertainty
61	I1	Indicator code for Cr
63-70	F8.4	Cr concentration (ppm)
71-78	F8.4	Cr analytical uncertainty
80	I1	Image sequence 2 for Card #2

Card #3

1-2	I2	Number of sample
4	I1	Indicator code for Cs
6-13	F8.4	Cs concentration (ppm)
14-21	F8.4	Cs analytical uncertainty
23	I1	Indicator code for Eu
25-32	F8.4	Eu concentration (ppm)
33-40	F8.4	Eu analytical uncertainty
42	I1	Indicator code for Fe
44-51	F8.4	Fe concentration (ppm)
52-59	F8.4	Fe analytical uncertainty
61	I1	Indicator code for K
63-70	F8.4	K concentration (ppm)
71-78	F8.4	K analytical uncertainty
80	I1	Image sequence 3 for Card #3

Card #4

1-2	I2	Sample number
4	I1	Indicator code for Mn
6-13	F8.4	Mn concentration (ppm)
14-21	F8.4	Mn analytical uncertainty
23	I1	Indicator code for Na
25-32	F8.4	Na concentration (ppm)
33-40	F8.4	Na analytical uncertainty
42	I1	Indicator code for Rb
44-51	F8.4	Rb concentration (ppm)
52-59	F8.4	Rb analytical uncertainty
61	I1	Indicator code for Sb
63-70	F8.4	Sb concentration (ppm)
71-78	F8.4	Sb analytical uncertainty
80	I1	Image sequence 4 for Card #4

Card #5

1-2	I2	Sample number
4	I1	Indicator code for Sc
6-13	F8.4	Sc concentration (ppm)
14-23	F8.4	Sc analytical uncertainty
23	I1	Indicator code for Se
25-32	F8.4	Se concentration (ppm)
33-40	F8.4	Se analytical uncertainty
42	I1	Indicator code for Zn
44-51	F8.4	Zn concentration (ppm)
52-59	F8.4	Zn analytical uncertainty
80	I1	Image sequence 5 for Card #5

Data Sample

The sample presented here is 3 units, 1 to 3, of the 25 records included in data set C4C2.

1234567890123456789012345678901234567890123456789012345678901234567890

01	1	10	40	11	37	12	23	1	1174	0	999	000	0	13.	2.	1		
01	0	18.8		0.7		0		240		90	0	0.33	0.01	0	0.5	0.1	2	
01	0	0.15		0.03		0	999	000		0		1170		20	0	9300	600	3
01	0	6.2		0.2		0		3780		80	0	18.	1.	0	0.017	0.005	4	
01	0	999		000		0	1.8	0.3		0	71.	1.					5	
02	1	05	48	06	52	997	00	3	1174	0	999	000	0	18.	2.	1		
02	0	44.		3.		0		350		160	0	0.172	0.009	0	3.4	0.1	2	
02	0	999		000		0	999	000		0		350	10	0	8400	600	3	
02	0	5.3		0.2		0		4090		80	0	7.5	0.4	0	0.024	0.006	4	
02	0	999		000		0	1.6	0.3		0	73.	1.					5	
03	1	13	47	16	53	997	00	4	1174	0	999	000	0	11.	2.	1		
03	0	6.9		0.3		0	999	000		0	0.147	0.006	0	0.5	0.1	2		
03	0	0.100		0.005		0		0.006	0.001	0		570	10	0	8200	600	3	
03	0	3.8		0.2		0		2250		40	0	11.4	0.5	0	0.024	0.006	4	
03	0	999		000		0	1.2	0.1		0	63.	1.					5	

QUALITY ASSURANCE

Objectives--

Same as data set C4C1.

Sampling Site--

Specimens were collected at sites A, B, C, and D described in data set C4C1 and shown in Figure 9.

Sample Collection--

Specimens of *Rana pipiens* were collected on shore and in the water with a nylon dip net, and placed in a plastic bag containing water from the site. Control specimens were collected on 8 Nov. 1974 before the start-up of the power plant. Test specimens were collected on 13 Aug. 1975 after start-up of the power plant.

Sample Preparation--

Frogs were washed individually with distilled-deionized water and stored in a freezer. All specimens were dissected in March 1976. By that time the frogs had dried to varying extents so that wet (fresh) weights for whole frogs and dissected organs are not available. The length of each frog was measured before dissection so that estimates of the ages of individual specimens were possible. The length was measured as the distance from the tip of the mouth to the anus. All specimens were dissected with stainless steel scalpels, forceps and scissors on glass and stainless steel trays inside a laminar flow hood prior to lypholization. All glassware and instruments were washed with "Micro" brand detergent, and rinsed in distilled water, distilled-deionized water, ethanol and again in distilled-deionized water. Utensils used to remove the organs were cleaned immediately before that operation and not used for any other purpose. Organs were removed whole by carefully cutting blood vessels and connective tissue and lifting them out with forceps. Skin samples were obtained in large pieces by a peeling action. All samples were placed in pre-weighed glass vials, and stored in the freezer after "fresh" weights were obtained. Notes were kept on the gut contents of each specimen. After freeze drying, composite samples of muscle tissue were made by grinding the tissue mechanically with stainless steel scissors until a fine, easily poured powder was obtained. As far as practicable, equal masses of tissue from each specimen were used to constitute the composite sample. The lypholized liver tissues were not ground prior to the preparation of composite samples. To ensure that the contribution of each specimen to the whole composite sample was similar for all specimens, large pieces of liver were trimmed by a pair of scissors prior to incorporation into the composite.

Analytical Procedure--

Same as data set C4C1.

A Comment--

In the absence of data showing how element concentrations change on a seasonal or daily basis, reasons for observed differences in element concentrations cannot be made. There are many reasons for suspecting that element concentrations vary naturally with time (to some extent) in a given location. For instance, concentrations of C, N and P vary considerably with reproductive cycles, seasons and availability of food in mollusks (Russell and Hunter 1970). Concentrations of Cd, Cr, Hg, Pb, and Zn in aquatic invertebrates are highest in the summer and early fall; seasonal variation in the concentration of these elements in river water were reported in a study of rivers in North Carolina (Weiss et al. 1972). It seems reasonable to expect that essential (and maybe non-essential) trace elements also vary in concentration in vertebrate organisms as conditions change. Examination of gut contents during dissection revealed that frogs collected in August were feeding more regularly than those collected in November. The diets of frogs collected in August were primarily prey of terrestrial origin (e.g. grasshoppers, flies, caterpillars); frogs collected in November were feeding solely on prey of aquatic origin.

Investigators--

Same as data set C4C1.

Supporting Documents

Same as data set C4C1.

REFERENCES

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- Flanagan, F. J. 1976. Descriptions and analyses of eight new USGS rock standards. Prof. Paper 840. U.S. Geological Survey, Reston, Virginia. 192 p.
- Helmke, P. A. and Glenn Hanson. In press. Impacts of coal combustion on trace elements in the environment. U.S. Environmental Protection Agency, Cincinnati Ohio.
- Koons, R. D., and P. A. Helmke. 1978. Neutron activation analyses of standard soils. *Soil Sci. Soc. Am. J.* 42:237-240.

National Bureau of Standards. 1979-1980. National Bureau of Standards Special Publication No. 260. C13.10:260/979-80. National Bureau of Standards, Washington, D.C. 102 p.

Russell-Hunter, W. D. 1970. A closer look at the bio-geochemistry of some elements. In: Aquatic productivity. The MacMillan Co., New York. p. 153-182.

Weiss, C. M., T. W. Yocum, and J. E. Minogue. 1972. Further characterization of the water quality of the New Hope and Lower Haw Rivers including benthic macro-invertebrate diversity and trace metal analyses. Report No. 73, Department of Environmental Science and Engineering, School of Public Health, University of North Carolina-Chapel Hill. 178 p.

SECTION 5 ORGANIC CONTAMINANTS

This subproject determined the impact of the Columbia Generating Station on levels of polycyclic aromatic hydrocarbons (PAH's) in the environment surrounding the power plant site. PAH's are a type of organic contaminant formed by the incomplete combustion of fossil fuels. The Columbia Generating Station is a potential source of PAH's; increased PAH levels are generally found in areas exposed to fallout from incomplete combustion of fossil fuels such as along highways, near airports, refineries and power plants. Research (Natusch 1975a,b, 1978) has indicated that PAH's exist as vapors in the stack and adsorb to particulates at cooler temperatures, usually within several feet of the stack, becoming concentrated in the particulates transported by the plume.

The principal goal was to measure deposition from the plume (atmosphere) contiguous to the Columbia Generating Station.

Specific objectives were: (1) To measure levels of selected PAH's in two soil types of high and low organic matter contents at various sites near the plant; (2) to measure levels of selected PAH's in large snow samples collected near the power plant; (3) to determine whether PAH levels increase cumulatively in the soil or are subject to seasonal fluctuations; and (4) to determine whether the soil acts as a sink for impinging PAH's.

In relation to objectives 1, 3, and 4, one study was conducted. The data collected are presented in data set C5A1, (Polycyclic aromatic hydrocarbons in soils surrounding the Columbia Generating Station (1977-78).

In relation to objective 2, one study was conducted. The data collected are presented in data set C5B1 (Polycyclic aromatic hydrocarbons in soils surrounding the Columbia Generating Station, 1977-78).

The investigators included J. M. Harkin, Professor; and Barbara Kaehler, Research Assistant; at the Department of Soil Science at UW-Madison. The report was compiled by Hilary McLellan, Data Analyst, Water Resources Center.

DATA SET C5A1: POLYCYCLIC AROMATIC HYDROCARBONS IN SOILS SURROUNDING
THE COLUMBIA GENERATING STATION (1977-78)

Data Summary

Investigators--

Barbara Kaehler and John Harkin.

Abstract--

This data set contains the results of analyses of soil samples collected in 1977 and 1978 from 11 sampling points within a 5-km radius of the Columbia Generating Station. Two types of soil samples were chosen for analysis, an organic soil and a sandy soil, both of which are characteristic of the area and represent extremes in sorptive capacity for extraneous organics. The presence of eight polycyclic aromatic hydrocarbons (PAH's) was tested for: benzo(a)pyrene (BP), perylene, pyrene, dibenzanthracene (DBA), benzoperylene, benzanthracene, chrysene, and phenanthrene.

Dates of Research--

26 Feb. 1977, 24 March 1977, 12 April 1977, 17 June 1977, 8 July 1977, 29 Oct. 1977, 8 Nov. 1977, 6 Feb. 1978, 21 March 1978, and 8 April 1978.

Data Form--

Computer file containing 137 units with one card-image/unit.

Data Format

Field Description--

<u>Column</u>	<u>Format</u>	<u>Description</u>
1-2	I2	Year
3-4	I2	Month
5-6	I2	Day
8	I1	Sample type; 1-snow, 2-mineral soil, 3-organic soil
10-11	I2	Site number
13-15	F3.1	Depth of sampling (cm)
18-20	I3	Ant-concentration
22-24	I3	Ba-concentration
26-28	I3	BaP-concentration
30-32	I3	BeP-concentration
34-36	I3	BaF + BbF-concentration
38-40	I3	BahP-concentration
42-44	I3	CHR-concentration
46-48	I3	COR-concentration
50-52	I3	DBaCA + DBaA-concentration

54-56	I3	FL-concentration
58-60	I3	PER-concentration
62-64	I3	PHE-concentration
66-68	I3	PYR-concentration
70-72	I3	TRI-concentration

Missing Data. Missing data are indicated by 9999.

Data Sample

The sample presented here is 10 records, 1 to 10, of the 137 records included in the complete data set C5A1.

1	1770226	2	01	0.0	991	020	400	992	000	580	993	380	000	020	998	040	080	005
2	1770324	2	01	0.0	991	010	320	992	998	600	993	310	000	040	998	100	095	005
3	1041277	2	01	0.0	991	005	050	992	010	500	993	050	000	035	000	090	060	010
4	1770617	2	01	0.0	005	998	040	010	998	080	998	035	000	010	000	060	030	000
5	1770708	2	01	0.0	010	000	020	005	998	050	010	020	000	010	000	050	010	000
6	1770708	2	01	2.5	998	000	998	000	998	005	000	010	000	999	000	010	999	000
7	1770708	2	01	5.0	998	000	998	000	000	998	000	010	000	998	000	998	998	000
8	1770708	2	01	20.	000	000	000	000	000	000	000	000	000	000	000	000	998	000
9	1771029	2	01	0.0	010	998	600	430	000	710	998	590	000	010	998	015	250	000
10	1771108	2	01	0.0	998	005	550	400	000	730	000	570	000	020	010	025	150	000

Quality Assurance

Objectives--

The goal of the research was to investigate whether fallout of PAH from the Columbia Generating Station represents a serious hazard to the surrounding land and water. Specific objectives included the following: (1) to measure the levels of selected PAH in two soil types of high and low organic contents at various sites near the plant; (2) to determine whether PAH levels increase cumulatively in the soil or are subject to seasonal fluctuation; and (3) to determine whether soil acts as a sink for impinging PAH.

Sampling Sites--

Soil samples were collected in a 5-km radius of the Columbia Generating Station at 11 sampling points (Figure 11). Information concerning the soil characteristics at each site are presented in Tables 4 through 14.

Sample Collection--

Surface samples were collected over an area of 1 m² in a quincunial pattern twice per season; sampling dates were approximately 3 weeks apart in each season. In July 1977 samples were collected at four depths (0, 2.5, 5.0, and 20.0 cm) at each of sites 1-9. For each sample, several kilograms of soil were collected with a small spade and transported to the laboratory in plastic bags.

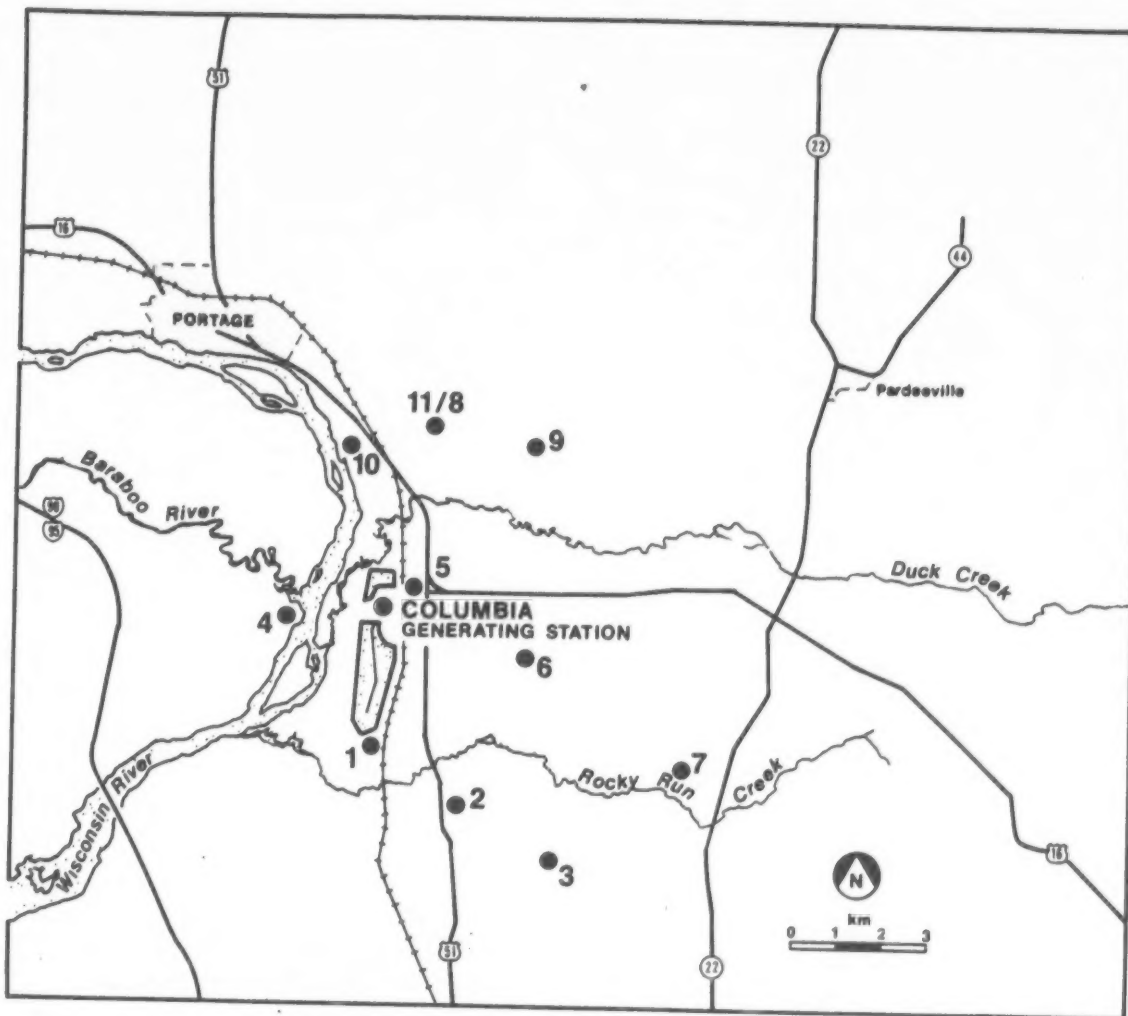


Figure 11. Sampling sites for soil in the vicinity of the Columbia Generating Station.

TABLE 4. CHARACTERISTICS OF THE SOIL AT SITE 1

Classification: Oshtemo series
 Location: NW $\frac{1}{4}$, SE $\frac{1}{4}$, Sec. 4, T.11N, R.9E., Portage Co., WI. 100 m W of
 railroad track, 65 m S of WPL cooling pond
 Topography: flat
 Drainage: moderately well
 Vegetation: short grasses; wild flowers; alfalfa
 Site selection criteria: proximity to the railroad

0-10 cm. Dark grayish brown^a (10YR 4/2) sandy loam; weak coarse granular;
 very friable; pH 8.0
 10-61 cm. Brown (10YR 5/3) medium sand; very weak coarse subangular blocky;
 very friable; 2 to 5% gravel; clear wavy boundary; pH 8.0
 61 cm. Grayish brown (10YR 5/2); coarse sands and gravels; loose; single
 grain; pH 8.5; effervescence

^aSoil colors are for the moist soil unless otherwise indicated.

TABLE 5. CHARACTERISTICS OF THE SOIL AT SITE 2

Classification: Made land
 Location: NW $\frac{1}{4}$, SE $\frac{1}{4}$, Sec. 11, T.11N, R9E., Portage Co., WI. 3 m E of
 U.S. Hwy. 51
 Topography: concave slope with 2% gradient to W.
 Drainage: moderately well at site, but variable within a short radius of
 the site due to characteristics of the landfill materials
 Vegetation: short grasses; wild flowers
 Site selection criteria: proximity to well-traveled highway

Entire profile. Assorted gravels and coarse sands; some finer soil at the
 surface (0-15 cm)

TABLE 6. CHARACTERISTICS OF THE SOIL AT SITE 3

Classification:	Boyer series
Location:	SW ¹ / ₄ , SW ¹ / ₄ , Sec. 13, T.11N., R9E., Portage Co., WI; 10 m upslope of patio of white house ¹ / ₄ km east of Stebbins Rd.
Topography:	concave slope with greater than 20% slope to the SW
Drainage:	Well to excessively well drained
Vegetation:	Short mowed grasses; wild flowers
Site selection criteria:	proximity to the side road
0-10 cm.	Brown (10YR 4/3) loamy sand; weak, medium granular; friable; clear, wavy boundary; pH 6.5
10-30.5 cm.	Yellowish brown (10YR 4/6) loamy sand; weak medium subangular blocky; very friable; clear wavy boundary; pH 7.0
30.5-41 cm.	Yellowish brown (10YR 4/6); loamy sand; loose, single grained; clear wavy boundary; pH 7.0
41 cm.	Strong brown (10YR 5/6) coarse sand; loose single-grain; few, small pebbles; pH 7.0

^aSoil colors are for the moist soil unless otherwise indicated.

TABLE 7. CHARACTERISTICS OF THE SOIL AT SITE 4

Classification:	Wyocena series
Location:	NW ¹ / ₄ , SW ¹ / ₄ , Sec. 28, T.12N, R.9E., 20 m W of Wisconsin River; due W of Columbia Power Station; at the end of a private road (Duples Rd.)
Topography:	concave slope of 3% gradient to the W
Drainage:	well-drained
Vegetation:	oak and hickory trees; red raspberries
Site selection criteria:	isolation of site from roads, railroads, farm vehicles
0-10 cm.	Dark brown (10YR 4/3) loamy fine sand; fine, loose, single-grain, very friable; abrupt wavy boundary; pH 5.0
10-20 cm.	Yellowish brown (10YR 4/6) loamy sand; fine, loose, single-grain; very friable; abrupt, wavy boundary; pH 5.0
20-46 cm.	Reddish brown (10YR 4/4) sandy loam; fine, loose, single-grain; friable; clear, wavy boundary; clayskins (5YR 4/6) bridging faces of the sand grains

TABLE 8. CHARACTERISTICS OF THE SOIL AT SITE 5

Classification: Boyer series
 Location: SW $\frac{1}{4}$, SE $\frac{1}{4}$, Sec. 27, T.12N, R.9E., Portage Co., WI, public observation area directly east of the Columbia Power Station; 3 m E and 2 m N or sign located W of U.S. Hwy. 51
 Topography: concave slope of 6% gradient to NE
 Drainage: well-drained
 Vegetation: chickory and burr plants
 Site selection criteria: proximity to Columbia Power Station and U.S. Hwy 51

Surface was apparently disturbed
 0-61 cm. Dark yellowish brown (10YR 4/4) medium sand; loose, single-grain; gradual, wavy boundary; pH 7.0
 61-102 cm. Strong brown (7.5YR 5/6) coarse sand; fragic; few small pebbles; wavy boundary; pH 7.0

TABLE 9. CHARACTERISTICS OF THE SOIL AT SITE 6

Classification: Boyer series
 Location: NW $\frac{1}{4}$, SE $\frac{1}{4}$, Sec. 35, T.12N, R.9E., Portage Co., WI. 3 m SW of the largest oak in the uncultivated area of the field 200 m S of North Star Rd.
 Topography: concave slope of 2% gradient to the S
 Drainage: well-drained
 Vegetation: oak opening; tall grasses
 Site selection criteria: isolation from roads

0-10 cm. Black (10YR 2/1) loamy fine sand; weak medium, granular; friable; abrupt, smooth boundary; pH 5.5
 10-20 cm. Black (10YR 4/3) loamy sand; weak, medium subangular blocky structure; friable; clear wavy boundary; pH 6.0
 20-31 cm. Dark brown (10YR 4/3); loamy sand; medium subangular blocky; very friable; clear wavy, boundary; pH 6.5
 31-35 cm. Dark brown (10YR 4/3); loamy sand; coarse, subangular blocky; very friable; clear wavy, boundary; pH 6.5
 35-51 cm. Yellowish brown (10YR 5/4) medium and coarse sand; single-grain; loose; pH 7.0

TABLE 10. CHARACTERISTICS OF THE SOIL AT SITE 7

Classification:	Wyocena series
Location:	SE $\frac{1}{4}$, NW $\frac{1}{4}$, Sec. 1, T.11N, R.9E., Portage Co., WI. 6 m W of Dunning Rd., 100 m N of Phillips Rd.
Topography:	concave slope of 1% gradient to the NE
Drainage:	well-drained; medium to rapid surface runoff
Vegetation:	quack grasses
Site selection criteria:	proximity to a lightly-travelled road
0-2.5 cm.	Dark brown (10YR 4/3) loamy sand; fine, loose, single grain; very friable; gradual wavy boundary; pH 6.5
2.5-30.5 cm.	Yellowish brown (10YR 4/6) loamy sand; fine, loose, single-grain; very friable; clear wavy boundary; common gravel interspersed; pH 7.0
30.5-46 cm.	Strong brown (7.5YR 5/6); medium sand; fine, loose, single-grain; clear wavy boundary; clayskins (5YR 4/6) bridging faces of the sand grains; common gravel; pH 7.0
46-51 cm.	Strong brown (7.5YR 4/6) medium sand; loose, single-grain; common gravel; pH 7.0

TABLE 11. CHARACTERISTICS OF THE SOIL AT SITE 8

Classification:	Boyer series
Location:	SW $\frac{1}{4}$, NE $\frac{1}{4}$, Sec. 15, T.12N, R.9E., Portage Co., WI, top of hillside overlooking Adrian Muck (Site 11) 8 m E of trees along the top of the ridge
Topography:	flat
Drainage:	well-drained
Vegetation:	short grasses; lichens; wildflowers
Site selection criteria:	proximity to adrian muck; proximity to railroad
0-10 cm.	Dark yellowish brown (10YR 4/4) loamy sand; weak, medium granular; friable; clear, wavy boundary; pH 6.5
10-20 cm.	Yellowish brown (10YR 4/6) loamy sand; weak, medium subangular blocky; very friable; gradual, wavy boundary; pH 7.0
20-31 cm.	Strong brown (10YR 5/6); coarse sand; loose single-grain; pH 7.0

TABLE 12. CHARACTERISTICS OF THE SOIL AT SITE 9

Classification: Plainfield series
 Location: SW $\frac{1}{4}$, NW $\frac{1}{4}$, Sec. 13, T.12N, R.9E., Portage Co., WI, near the
 boundary of short trees, 4 m E of meadow edge, 6 m S of Hwy G.
 Topography: flat
 Drainage: excessive
 Vegetation: Lichens; horsetails; British soldiers; short grasses
 Site selection criteria: proximity to moderately-travelled side-road

0-15 cm. Brown (10YR 4/3) loamy sand; weak, medium granular; very friable;
 gradual, wavy boundary; pH 5.5
 15-30 cm. Dark yellowish brown (10YR 4/4) sand; weak, medium granular;
 loose; gradual wavy boundary; pH 5.5
 30.5 cm. Yellowish brown (10YR 5/6); coarse sand; single-grain; gradual,
 wavy boundary; common small pebbles; pH 6.0

TABLE 13. CHARACTERISTICS OF THE SOIL AT SITE 10

Classification: Alluvial land, wet
 Location: SW $\frac{1}{4}$, NE $\frac{1}{4}$, Sec. 16, T.12N, R.9E., Portage Co., WI, directly
 across from the "stop ahead" sign on the first unmarked road W of U.S.
 Hwy. 51 and County Trunk P intersection
 Topography: convex slope of 1% gradient to the E
 Drainage: very poorly drained; nearly level area of the floodplain
 Vegetation: oak forest; ferns; mosses
 Site selection criteria: proximity to railroad; comparison to Adrian Muck
 (Site 11)

0-127 cm. Black (10YR 2/1) sapric material; primarily herbaceous fibers
 with some distinguishable oak leaf fragments; strong, platy

TABLE 14. CHARACTERISTICS OF SOIL AT SITE 11

Classification:	Adrian Muck
Location:	SW $\frac{1}{4}$, NE $\frac{1}{4}$, Sec. 15, T.12N, R.9E., Portage Co., WI, swamp area at the bottom of hill site 8 is located on, at the end of the roadway into the preserve area N of County Trunk P
Topography:	concave hill, site located on flat area at the bottom
Drainage:	very poorly drained; surface runoff and internal drainage is very slow
Vegetation:	wild onions; sedges; swamp grasses
Site selection criteria:	proximity to railroad; position in landscape; proximity to site 8
0-61 cm.	Black (10YR 2/1) sapric material; primarily herbaceous fibers; strong, platy; abrupt, wavy boundary
61 cm.	Dark brown (10YR 4/3) fine sand; single-grain; loose

Sample Storage--

In the laboratory, miscellaneous organic debris was removed from the samples. Next the samples were transferred to Kraft paper bags (Shabad et al. 1971) and air dried. After drying, the soil aggregates were broken down with a mortar and pestle. Stones and gravel were sieved out with a U.S. Number 18 standard sieve.

Analytical Materials and Equipment--

Spectroscopic quality solvents were obtained from Aldrich Chemicals (Milwaukee, WI 53233), Burdick and Jackson (Muskegon, MI 49442), and North Central Chemicals (Madison, WI 53702). All solvents were redistilled in a glass distillation apparatus. To determine the solvent purity, a 300 ml aliquot was reduced in volume to roughly 0.5 ml and 2.0 ml was analyzed on each of the liquid phases used for gas-liquid chromatography. All redistilled solvents were stored in amber glass bottles. All extracts and samples requiring storage were kept in glass vessels in the dark at -15°C .

Authentic samples of pure PAH for use as chromatographic standards were obtained from various sources including Aldrich Chemicals, Eastman Organic Chemicals (Rochester, NY 14560), and McArdle Laboratory for Oncology Research at the University of Wisconsin (Madison, WI 53706). All non-carcinogenic PAHs were recrystallized from glacial acetic acid or toluene; carcinogenic PAHs were not recrystallized. Analytical standards used for TLC and GLC analyses were not kept for more than 3 months. Crystalline standard compounds were weighed out on a Mettler H54 (Hightstown, NJ) analytical balance, dissolved in dichloromethane in 5 ml volumetric flasks, and stored. Mixtures of these compounds were prepared as needed and used as external and internal standards. The concentrations of PAH in environmental samples were determined by comparing peak heights and/or areas with those of the external standards.

A planimeter was used to determine peak area; an automated peak height integrator was not available.

Extraction of Organic Materials from Soils--

One hundred grams of the sandy soils (sites 1-9) and 20 to 50 g of the organic soils (sites 10-11) were extracted in a Soxhlet extractor with 300 ml of benzene for 48 hr (Borneff and Fischer 1962, Kaisaki 1978). Make-up benzene was added as necessary and the Soxhlet extractors were covered with aluminum foil to prevent photo-decomposition of PAH during the extraction process. When the soil was weighed prior to the extraction procedure, a subsample of the air-dried soil was taken and the moisture content determined. In subsequent calculations the weight of the soil was corrected to account for the weight of the water.

Selective Oxidation--

The second preparatory step for soil samples was selective oxidation (Hansen and Schnitzer 1967). The benzene extract was evaporated to dryness on a Rotovapor-R and 25 ml of redistilled 2-methyl-2-propanol (t-butanol), 2 ml of 10% (w/w) KOH and 100 mg (for sands) or 200 mg (for mucks) reagent grade potassium permanganate (KMnO_4) (Allied Chemical, Morristown, NJ) were added to the reaction flask. This mixture was refluxed for 45 to 60 min until the purple permanganate color had disappeared. After cooling, 20 ml of distilled water was added to increase the density in the alcohol layer and separation of the PAHs was effected by three extractions with 25 ml of dichloromethane. The volume of the extract was reduced on the Rotovapor-R to approximately 2 ml which was kept for separation by TLC.

Thin-Layer Chromatography--

TLC was used to separate PAH from extraneous organics in the extract. Samples were spotted along a line 1 cm from the unscribed edge of a 20 x 20 cm glass plate previously coated with 0.5 mm Silicar TLC-7G (Mallinckrodt, St. Louis, MO) and activated at 100°C for 1 hr. These plates were developed in 5% (v/v) carbon tetrachloride in cyclohexane at room temperature for 45 to 75 min. A standard PAH mixture also was spotted on the plate to compensate for daily variations in room temperature and plate characteristics which affect development time.

The PAH band determined by visual inspection under a UVSL-25 Mineralight (Ultraviolet Productions, Inc., San Gabriel, CA) was removed using a mini-extractor modified by Kaisaki (1978). Extraction with dichloromethane (3 x 25 ml) followed. The volume was reduced and the sample quantitatively transferred to a 1 ml volumetric flask.

When it was necessary to keep extracted samples for extended periods, the thin layer separation was not performed until the samples were ready to be analyzed. This reduced losses due to PAH decomposition. After the selective oxidation, samples to be held for more than 2 weeks were stored in 30 ml glass-stoppered vials.

Gas Liquid Chromatography--

A model 7400 Packard gas chromatograph equipped with a model 847 temperature programming unit, a model 843 dual electrometer, a model 835 power supply unit and a model 873 deviation control package (Packard Instruments; Chicago, IL) was used to analyze sample mixtures. Pre-purified N_2 (30 ml per min) was the carrier gas. Six foot, 2 mm (I.D.), modified glass columns were used (Kaisaki 1978). Acid-washed, dimethyldichlorosilane-treated Chromosorb P (Analabs, Inc., North Haven, CT), 100/120 mesh, was used as the solid support. Several combinations of liquid phases and loading rates confirmed compound identification.

Two flame ionization detectors, 1×10^{-11} and 3×10^{-11} A.F.S. sensitivity, were used. The temperature of the injection block was 240°C ; the detector temperature was 310°C .

Temperature programming was utilized for the initial analyses on OV-17 (Applied Science Laboratories, State College, PA 16801). The initial temperature was 130°C with a 4 min linear increase to 280°C ; the program remained at this temperature for an additional 4 min. To confirm the identity of specific compounds, isothermal (190°C) analyses on BBT (Eastman Organic Chemicals) were used.

An initial run was performed on an OV-17 column to determine the complexity of the mixture. The trial chromatogram was compared to a chromatogram of a standard mixture and major peaks tentatively identified by retention times. Subsequent runs were made of samples spiked with known compounds. Further confirmation of their identity was made by repeating this process on the second liquid phase, BBT. Some isothermal runs were made on OV-17 to effect separation of isomeric compounds when temperatures $>190^\circ\text{C}$ were required.

Quality Control--

During routine sample analyses care was exercised to maintain quality control. Standard solutions were kept a maximum of 3 months. All standards and samples were stored in the dark at -15°C .

Precautions were taken to minimize photodecomposition. The laboratory was equipped with yellow fluorescent lights and samples were protected by aluminum foil during the Soxhlet extraction to prevent photodecomposition of PAH (Kuratsune and Hirohata 1962).

GLC parameters such as flow rate were routinely monitored. A blank run through the temperature program was completed at the start of each day to determine the stability of the base line. A mixture of standard compounds of known concentrations was analyzed every third to fifth run of the gas chromatograph; this data was the basis for determining PAH concentrations in the samples. Columns packed with OV-17 were conditioned for 1 hr at 150°C , then at 310°C for 24 hr. Columns packed with BBT were conditioned at 310°C until a stable baseline was obtained. After every sixth or seventh run the column was reconditioned for 3 hr to remove residual compounds. The flow

rate for the carrier gas was reduced and the detector discontinued during the conditioning and reconditioning process.

The liquid crystals deteriorated rapidly when environmental samples were analyzed; these columns were repacked every 5 days (approximately 40 runs). Columns packed with OV-17 were conditioned for 1 hr at 150°C, then at 310°C for 24 hr. Columns packed with BBBT were conditioned at 310°C until a stable baseline was obtained. After every sixth or seventh run the column was reconditioned for 3 hr to remove residual compounds. The flow rate for the carrier gas was reduced and the detector discontinued during the conditioning and reconditioning process.

The liquid crystals deteriorated rapidly when environmental samples were analyzed; these columns were repacked every 5 days (approximately 40 runs). Columns packed with OV-17 were much more stable and were repacked every 150-200 runs. All columns were hand packed. Special care was exercised with small mesh supports to avoid physical destruction of the particles.

Glassware was cleaned with a hot chromic acid solution, rinsed with 3N HCl acid and distilled water. Glass chromatography columns were cleaned in the same way and rinsed with methanol, acetone, and chloroform. Columns were treated for 5 min. with 10% (v/v) dimethyldichlorosilane in toluene, rinsed with methanol, and dried before packing. Silanized glass wool was used.

Chromosorb P, the solid support, was treated with dimethyldichlorosilane to provide an inert surface; this treatment reduces peak tailing due to surface adsorption. Silanized supports are hydrophobic and are not wetted by polar phases. Mineral contaminants were removed and surface activity reduced by acid washing of the support.

Chromosorb P is prepared from Johns-Manville's Sil-O-Cel C22 Firebrick and can hold up to 30% liquid phase (Analabs 1977). The Chromosorb support series is typically used to analyze aromatic hydrocarbons and other low polarity compounds.

Initially, it was deemed necessary to determine the magnitude of PAH loss due to the preparation-separation procedure. Decreased yield may be due to the extraction process, solvent partitioning, and inter-vessel transfer. The amount of organic material extracted is dependent on the characteristics of the samples and the extraction conditions. The latter were controlled by strict replication of conditions; several replicate sets were analyzed to test the constancy of the extraction process. Sample homogeneity is difficult to control; however, soil samples which had similar physical-chemical characteristics were selected. Soil pH and percent organic C were determined for all samples to provide a measure of sample uniformity (data set C5B1). Water pH (Liegel and Schulte 1977) was determined in the laboratory. Organic C contents were determined for the first sample set by combustion (Love et al. 1977) and titration (Liegel and Schulte 1977). These values were compared; since there was close agreement between the methods, the combustion method was chosen for its speed and simplicity.

There is some loss associated with transfer from one vessel to another. This loss was minimized by reducing the number of such transfers and by employing careful quantitative technique. Some loss of the more volatile compounds cannot be avoided.

Losses due to the preparatory steps were determined. Three paired treatments were analyzed to determine the percent PAH lost. Treatments I and II tested for losses due to the selective oxidation procedure. The effect of storage on PAHs was determined by Treatment III. Fourteen standard compounds of known concentration were placed in each of six round-bottomed flasks. Treatments I and II received 100 mg and 200 mg of KMnO_4 respectively in the selective oxidation. These four samples were analyzed according to the described procedure. GLC analysis was performed within 2 hr of the TLC separation. To determine the percentage yield, chromatograms of the standard mixture without prepurification were compared to those receiving the various treatments. The liquid phase was OV-17 for the GLC analysis of the three treatments.

There are significant differences between the yields of specific compounds within a given treatment due to differences in compound volatility, stability, and molecular geometry. Therefore, an average percent yield was determined for each compound. For given compounds, no significant differences existed between the three treatments, so an average yield was determined by grouping all six trials; the standard deviation was calculated for each average. These yield determinations were assumed to be for the worst case and observed sample concentrations were corrected accordingly. It was not possible to determine extraction efficiency

SUPPORTING DOCUMENTS

Organic contaminants. In: Documentation of environmental change related to the Columbia Electric Generating Station. Institute for Environmental Studies, Reports 69, 82, and 92. Univ. of Wisconsin-Madison.

DATA SET C5B1: POLYCYCLIC AROMATIC HYDROCARBONS IN SNOW SURROUNDING
THE COLUMBIA GENERATING STATION (1977-78)

Data Summary

Investigators--

Barbara Kaehler and J. M. Harkin.

Abstract--

This data set contains the results of analyses of snow samples, from four sampling points within a 5-km radius of the Columbia Generating Station. Samples from each site were obtained on five dates. The presence of eight polycyclic aromatic hydrocarbons (PAH's) was tested for: benzo(a)pyrene (BP), perylene, pyrene, dibenzanthracene (DBA), benzoperhylene; benzanthracene, chrysene, and phenanthrene.

Dates of Research--

1977 to 1978

Data Form--

Computer file containing 12 units with one card-image per unit.

Data Format

See data set C5A1.

Data Sample

The sample presented here is the complete data set C5B1.

1	1770107	12	1	0.0	1	991	000	120	992	000	150	993	090	000	010	080	020	150	000
2	1770212	12	1	0.0	1	991	998	180	992	000	190	993	080	000	015	090	015	190	998
3	1771129	12	1	0.0	1	998	015	210	060	000	230	998	120	000	020	040	030	250	080
4	1780110	12	1	0.0	1	015	998	140	060	000	140	010	120	000	998	060	010	130	080
5	1780208	12	1	0.0	1	998	010	130	060	000	150	998	120	000	100	040	010	140	998
6	1771129	13	1	0.0	1	015	010	150	060	000	180	998	040	000	050	080	015	190	998
7	1780110	13	1	0.0	1	015	998	080	040	000	140	030	020	000	065	080	010	250	998
8	1770107	14	1	0.0	1	991	000	180	992	000	190	993	150	000	998	998	200	999	080
9	1770212	14	1	0.0	1	991	000	150	992	000	200	993	110	000	010	998	100	999	998
10	1771129	14	1	0.0	1	020	000	100	080	000	180	040	100	000	010	010	120	999	000
11	1780110	14	1	0.0	1	998	000	190	060	000	180	998	150	000	010	998	020	999	040
12	1780208	14	1	0.0	1	998	998	095	060	000	120	998	000	000	998	998	015	999	000

Quality Assurance

Objectives--

The goal of this study was to measure levels of selected PAH's in snow samples collected near the power plant. These data were used to assess whether PAH levels increase cumulatively in the area or are subject to seasonal fluctuations.

Sampling Sites--

Snow samples were collected from four sampling points within a 5 km radius of the Columbia Generating Station (Figure 12).

Sample Collection--

Two samples were collected from each site approximately 48 hr after a snowfall event. In 1977, samples were melted in the field using a Browning Pocket Stove. This proved to be inefficient due to the large sample sizes required so in 1978 the samples were collected in large plastic garbage bags and brought frozen to the laboratory, where they were melted over a water bath.

Analytical Materials and Equipment--

Same as data set C5A1.

Extraction of Organic Materials from Snow--

Within 24 hr of sample collection, the samples were extracted with three portions of dichloromethane (10:1 v/v). A total of 10 liters was extracted in 1.5 liter aliquots in a 2 liter separatory funnel. Each portion was shaken three min for the first extraction and 1 min for each of the last two extractions to effect complete separation. The volume of the extract was reduced to approximately 2 ml on a Rotovapor-R (M. Buchl, Switzerland; available through Rinco Instrument Co., Inc., Greenville, IL).

The extracts from organic soils were filtered (1.0 pore size, Millipore Teflon Filter, Millipore Corp., Bedford, MS) to remove particles which had passed into the receiving flask.

Selective Oxidation--

The organic component of the snow extract is much less complex than that of the soil extract, so this preparatory step is unnecessary.

Thin-Layer Chromatography--

Same as data set C5A1.

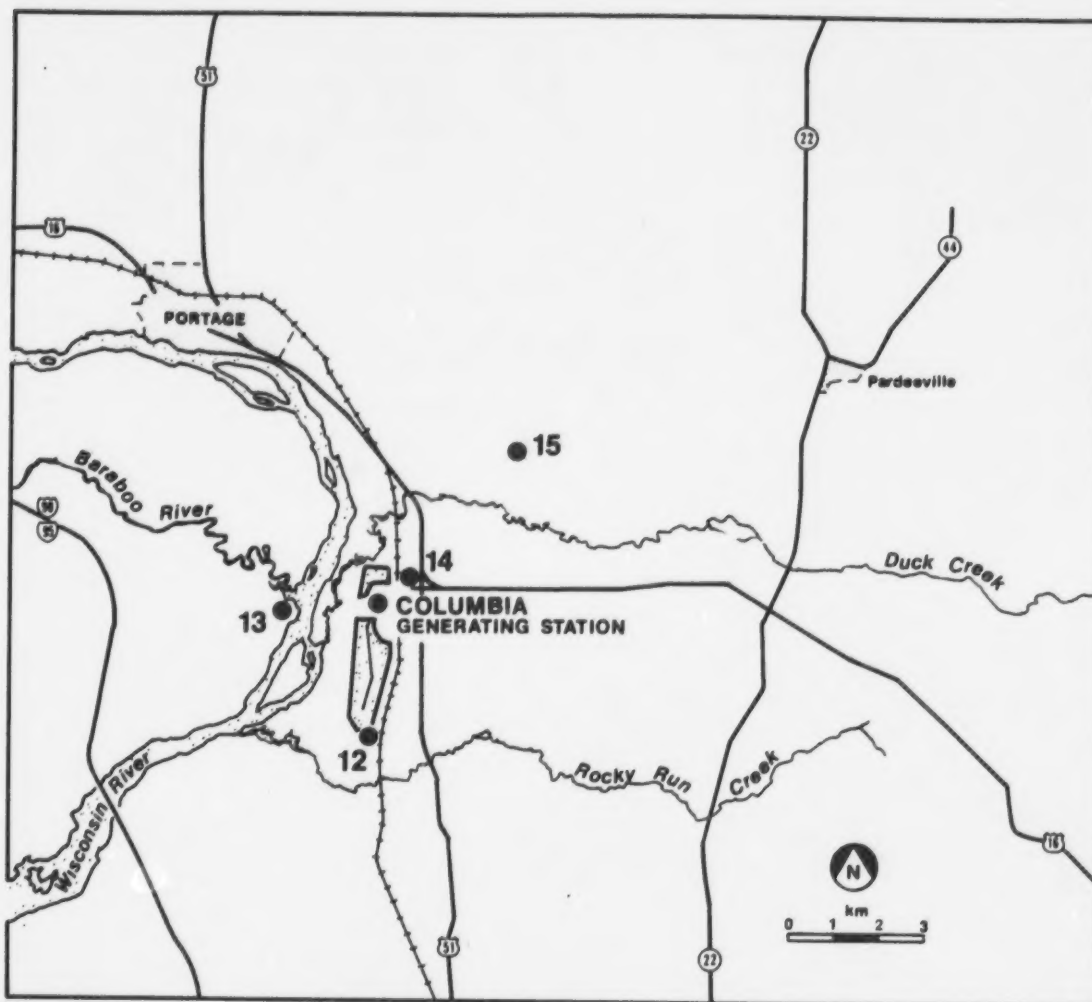


Figure 12. Sampling sites for snow in the vicinity of the Columbia Generating Station.

Gas Liquid Chromatography--

Same as data set C5A1.

Quality Control--

Same as data set C5A1.

Supporting Documents

Organic contaminants. In: Documentation of environmental change related to the Columbia Electric Generating Station. Institute for Environmental Studies, Reports 69, 82, and 92. University of Wisconsin-Madison.

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SECTION 6

AIR POLLUTION MODELING

The goal of the Air Pollution Modeling subproject was to characterize air quality in the vicinity of the Columbia Generating Station and to assess the station's environmental impact. The specific objectives of the air pollution group were: (1) to measure air pollutant deposition; (2) to analyze the fixed site monitoring data; and (3) to develop a computer simulation of the atmospheric plume as it impacts various receptor points in the study region.

In relation to objective (1), a study of air pollution deposition was conducted and the data are presented in data set C6A1. Data set C6A1 (Measurement of sulfur dioxide by deposition in the plume of the Columbia Generating Station (1976-77)) documents the results of eight tests that measured the dry deposition flux of SO_2 in the plume.

The actual collecting of fixed site monitoring data objective (2) was executed by the Wisconsin Power and Light Company and is presented in section 17. To meet objective (3), the Gaussian plume model was modified for conditions at the Columbia Generating Station, and simulated levels of SO_2 were compared with observed levels. The model is presented in "Air pollution studies near a coal-fired power plant" (Ragland et al. 1980).

The investigators were K.W. Ragland, Associate Professor, Terry L. Coughlin, Research Assistant, and Bradley D. Goodell, Research Assistant, Department of Mechanical Engineering at the University of Wisconsin-Madison. The report was compiled by Saya Shacham, Data Analyst, Water Resources Center.

DATA SET C6A1: MEASUREMENT OF SULFUR DIOXIDE DRY DEPOSITION IN THE PLUME OF THE COLUMBIA GENERATING STATION

Data Summary

Investigators--

K.W. Ragland and T.L. Coughlin.

Abstract--

The dry deposition of SO_2 from the Columbia Generating Station was measured by means of the gradient transfer method. Eight complete tests

were obtained at eight different sites during the period August 1976 to February 1977. At each site, measurement of wind speed, temperature, and SO₂ concentrations were made simultaneously through teflon tubes at heights of 0.125, 0.25, 0.50, 1.0 and 2.0 m above the height of the vegetation canopy. In addition, the canopy height and observations about soil and cloudiness were recorded.

Dates of Research--

August 1976-February 1977.

Data Form--

Computer file containing 8 units with two card-images/unit.

Data Format

Field Description--

Card #1

<u>Column</u>	<u>Format</u>	<u>Description</u>
1-2	I2	Month
3-4	I2	Day
5-6	I2	Year
8-11	I4	Time of day
13	I1	Site description; 1=pasture, 2=marsh, 3=tall prairie, 4=snow covered field, 5=cut alfalfa, 6=wetland
15	I1	Soil condition; 1=dry, 2=moist, 3=damp, 4=wet
17-18	I2	Percent cloudiness
20-23	F4.1	Canopy height (cm)
25-30	F6.3	Richardson number at 1 m
32-35	F5.1	Altitude 1; above canopy (m)
38-41	F4.2	Wind speed at altitude 1 (m/sec)
43-46	F4.1	Temperature at altitude 1 (°C)
48-50	I3	Concentration SO ₂ at altitude 1 (µg/m ³)
52-56	F5.1	Altitude 2; above canopy (m)
58-61	F4.2	Wind speed at altitude 2
63-66	F4.1	Temperature at altitude 2 (°C)
68-70	I3	Concentration SO ₂ at altitude 2 (µg/m ³)
80	I1	Image sequence, 1 for card #1

Card #2

12-16	F5.1	Altitude 3; above canopy (m)
18-21	F4.2	Wind speed at altitude 3 (m/sec)
23-26	F4.1	Temperature at altitude 3 (°C)
28-30	I3	Concentration of SO ₂ at altitude 3 (µg/m ³)
32-35	F5.1	Altitude 4; above canopy (m)
38-41	F4.2	Wind speed at altitude 4 (m/sec)

43-46	F4.1	Temperature at altitude 4 (°C)
48-50	I3	Concentration SO ₂ at altitude 4 (µg/m ³)
52-56	F5.1	Altitude 5; above canopy (m)
58-61	F4.2	Wind speed at altitude 5 (m/sec)
63-66	F4.1	Temperature at altitude 5 (°C)
68-70	I3	Concentration SO ₂ at altitude 5
80	I1	Image sequence, 2 for card #2

Data Sample

The sample presented here is the complete data set C6A1.

1234567890123456789012345678901234567890123456789012345678901234567890

081176	1700	1 9 99	16.0 -0.053	2.00	2.50 32.3	49 1.00	2.15 32.8	47	1
		0.50	1.58 33.3	50 0.25	1.28 34.0	43 0.125	0.36 36.4	31	2
092276	1320	2 4 10	81.0 -0.035	2.31	2.41 20.7	87 1.31	1.75 23.6	80	1
		0.81	0.90 25.8	69 0.56	0.74 25.0	60 0.43	0.36 24.1	51	2
092976	1400	5 1 00	15.5 -0.058	2.00	3.87 17.1	149 1.00	3.33 17.7	147	1
		0.50	2.80 18.5	142 0.25	2.18 19.9	139 0.125	1.01 21.2	127	2
100776	1425	3 3 30	66.0 -0.19	2.00	1.72 12.2	50 1.00	1.20 13.6	37	1
		0.50	1.15 14.8	36 0.25	0.66 16.8	39 0.125	0.22 19.3	37	2
100776	1630	1 2 30	6.0 0.0	2.00	2.44 999	65 1.00	2.02 999	64	1
		0.50	1.74 999	60 0.25	1.43 999	43 0.125	0.92 999	57	2
121076	1520	2 1 30	80.0 -0.016	2.50	4.39 6.4	58 1.50	3.13 6.7	52	1
		1.25	2.82 7.1	56 1.00	2.22 8.2	54 0.75	1.05 9.6	52	2
021577	1245	4 4 00	0.0 0.0	2.00	4.72 1.0	130 1.00	4.21 999	126	1
		0.50	3.67 999	123 0.25	2.94 999	118 0.125	2.54 1.0	115	2
030877	1300	6 4 00	999 -0.011	2.00	3.85 16.8	63 1.50	3.50 999	61	1
		1.00	2.76 17.4	61 0.75	1.96 18.0	59 0.50	1.75 18.0	53	2

Quality Assurance

Objectives--

The objective of this study was to measure the dry deposition flux of SO₂ directly in the plume. Determination of the deposition rate is important because it represents an input to the ecosystem and because it can be an important factor in estimating ambient air concentration further downwind.

Sampling Location--

To locate the plume, SO₂ and O₃ analyzers were operated simultaneously from an automobile. The plume was located when the SO₂ level increased and the O₃ level decreased. (The decrease in O₃ is caused by NO scavenging the O₃ to form NO₂.) Once the plume was located, the area was traversed until the plume was shown to be near the maximum ground level position or at least > 30 µg/m³. The equipment was set up at a suitable nearby site, a site with a large uniform surface canopy. As there was not time to request access to private property, areas where trespassing was a problem were avoided.

Data Acquisition--

Thirty-five attempts were made during 1976 and 1977 to track the plume. Because of the transient nature of the plume, however, only eight complete tests were obtained. These tests were conducted in pasture land, marshes, and prairie; on one occasion they were conducted when there was snow on the ground. Tests conducted under neutral atmospheric conditions were more satisfactory than tests conducted during unstable conditions even though the concentration was lower. The procedure was more difficult than anticipated and should not be expected to yield results readily.

Equipment--

The transient nature of the plume and the advantages of testing in many types of terrain required that equipment be portable, compact, easy to assemble, and self-powered. The following equipment was used:

- (1) Meloy, Inc., SO₂ Analyzer Model SA165 with a sample flow rate of 200 ml/min.;
- (2) Rimco cup anemometers with a built-in light system to count the number of revolutions of each anemometer;
- (3) Esterline-Angus Portable Strip-Chart Recorder;
- (4) iron-constantin thermocouples (radiation-shielded), ice bath, stepping switch, and Wheatstone bridge;
- (5) Bendix Air-Sampling Pump Model BDX-44;
- (6) Teflon air-sampling bags fitted with Teflon tubing and mounted in plexiglas chambers; and
- (7) aluminum mast, 2.2-m high, with five brackets each capable of positioning a cup anemometer, Teflon tube, and thermocouple.

Measuring Procedure--

At each site, measurements of wind speed, temperature, and SO₂ concentration were made simultaneously at heights of 0.125, 0.25, 0.50, 1.0, and 2.0 m above the height of the vegetation canopy. The mast could make small height adjustments, but in the case of tall canopies only three measuring heights were used: 0.50, 1.0, and 2.0 m. Care was taken in setting up the instruments so as not to disturb the upwind and downwind canopy.

The SO₂ profiles were determined by sampling at the five heights simultaneously through small Teflon tubes. The ambient air was drawn through the tubes into teflon bags by pumping a slight vacuum in the plexiglas box. After a sampling period of 15 min, the ends of the sampling tubes were sealed, and each bag was connected to the SO₂ analyzer.

The SO₂ analyzer and the bags were calibrated before each test with a Metronics Dynocalibrator equipped with a SO₂ permeation tube.

Investigators--

The data were collected by Terry L. Coughlin and a field assistant. At the time of the study, T.L. Coughlin was working toward an M.S. degree in Mechanical Engineering at the University of Wisconsin-Madison. The study was supervised by Professor K.W. Ragland.

Supporting Documents

Air-pollution modeling. In: Documentation of environmental change related to the Columbia Electric Generating Station. Institute for Environmental Studies, Reports 69 and 82, University of Wisconsin-Madison.

Ragland, K.W., B. Goodell, and T. Coughlin. In press. Air pollution studies near a coal-fired power plant. EPA-600/3-80-048. U.S. Environmental Protection Agency, Cincinnati, Ohio.

SECTION 7

METEOROLOGY

The subproject deals with monitoring the meteorological conditions in the vicinity of the Columbia Generating Station (1) to help determine how materials from the generating station are transported through the atmosphere, and (2) to determine possible climatic effects of the generating station and its cooling lake. Specific objectives were: (1) to measure those characteristics of the atmosphere necessary to determine possible relationships between the observed meteorological parameters and ground level concentrations of material from the smoke stack, and (2) to monitor atmospheric inversion patterns in the vicinity of the Columbia Generating Station to determine the maximum height to which stack emissions may be dispersed. Other meteorological data were collected in the vicinity of the Columbia Generating Station site for Wisconsin Power and Light Co. by Dames and Moore Consultants and are presented in Section 17.

Relating to objective (1), five data sets were obtained to monitor the time series of three-dimensional wind components, the vertical air temperature gradients, solar radiation, and rainfall. The data collected in these studies are presented in data sets C7A1-C7A5. Data set C7A1 (Wind Speed Near the Columbia Generating Station, 1976-77) contains hourly average records of wind speed at the Messer, Dekorra, Wyocena, and Cemetery monitoring stations (Figure 13). Data set C7A2 (Wind Direction Near the Columbia Generating Station, 1976-77) contains hourly average records of wind direction at the Messer, Dekorra, Wyocena, and Cemetery monitoring stations. Data set C7A3 (Air Temperature Gradients Near the Columbia Generating Station, 1976-77) contains records of temperature differences for five gradients at the Messer site. Data set C7A4 (Solar Radiation Monitoring Near the Columbia Generating Station, 1976-77) presents hourly average records of two types of monitoring at the Messer site; solar radiation and net radiation. Data set C7A5 (Rainfall Monitoring Near the Columbia Generating Station, 1972-76) presents noncontinuous records of starting and stopping times for each storm event and the amount of rainfall between the months of April and October during each year at the four sites. Data set C7B1 (Inversion Layer Monitoring Near the Columbia Generating Station, 1976-77) presents hourly average records of five types of continuous measurement obtained with an acoustic sounder to determine the height of the inversion layer: sodar lowest base, sodar lowest top, sodar higher base.

The investigators were Charles R. Stearns, Associate Professor; Phillip Falconer, Research Assistant; George Weidner, Research Assistant; Eric

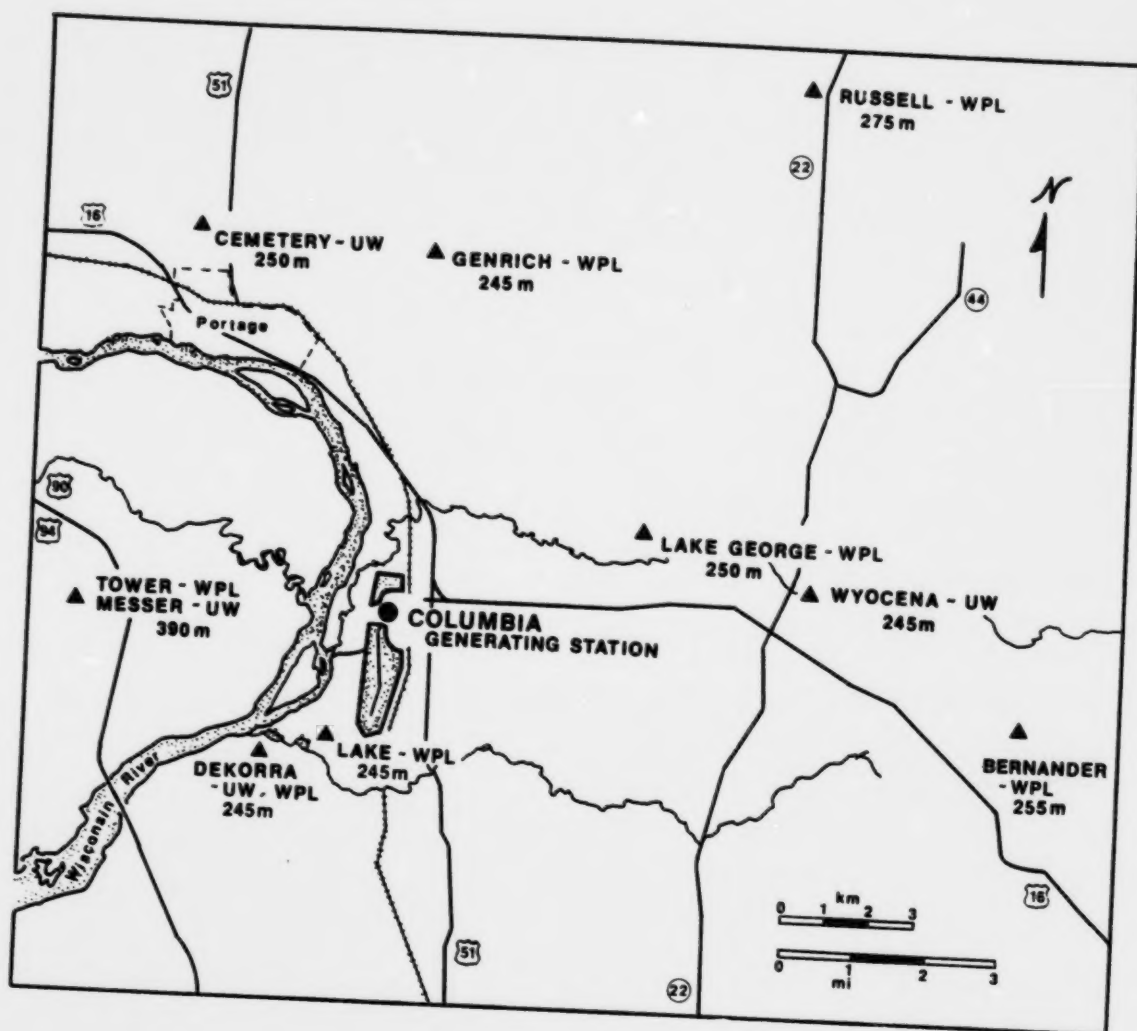


Figure 13. The Columbia Generating Station with air quality and meteorology monitoring stations.

Hennen, Research Assistant; Brent Bowen, Research Assistant; Leonard Dzamba, Research Assistant; Department of Meteorological and Space Science, University of Wisconsin-Madison. The report was compiled by Hilary McLellan, Data Analyst, Water Resources Center.

DATA SET C7A1: WIND SPEED NEAR THE COLUMBIA GENERATING STATION (1976-77)

Data Summary

Investigators--

P. Falconer, G. Weidner, E. Hennen, B. Bowen, L. Dzamba, and C. R. Stearns.

Abstract--

This data set contains hourly average records of wind speed (m/sec) at four monitoring sites located 4.2 to 9.7 km from the Columbia Generating Station. At the Wyocena, Dekorra, and Cemetery sites, wind speed was monitored continuously at a height of 9 m. At the Messer site, wind speed was monitored continuously at two heights, 2 m (one monitor) and 32 m (two monitors).

Dates of Research--

1976-77.

Data Form--

Computer file containing 8,404 units with one card-image/unit.

Data Format

Field Description--

The following field description is a modified version of the Storage and Retrieval Aeromatic Data (SAROAD) format developed by the U.S. Environmental Protection Agency.

<u>Column</u>	<u>Format</u>	<u>Description</u>
1	I1	Card format identification; 1=multiple
2-3	I2	State code; 51=Wisconsin
8-10	I2	Parameter code (32, 34, 35, 43, 53, 63) ⁷
11	A1	Agency type: F=state agency

⁷Each parameter code number identifies a measurement within this data set (see Table 15).

12-13	I2	Project classification; 02=source oriented ambient surveillance
14	I1	Sampling time interval; 1=1 hr
15-16	I2	Year
17-18	I2	Month
19-20	I2	Day
21-22	I2	Sampling start hour; 00=midnight, 12=noon
32	I1	Decimal locator; indicates number of digits from the right for placement of decimal point
33-80	I2I4	Hourly observations (m/sec)

TABLE 15. MEASUREMENTS INCLUDED IN DATA SET C7A1

Parameter code number in field description	Site	Height of measurement (m)	No. of units in file	Sensor	Dates
32	Messer	32	1,462	Beckman-Whitley	1/76-12/77
34	Messer	32	1,462	Stewart anemometer	1/76-12/77
35	Messer	2	1,462	Stewart anemometer	1/76-12/77
43	Wyocena	9	1,278	Stewart anemometer	1/76- 9/77
53	Dekorra	9	1,462	Stewart anemometer	1/76-12/77
63	Cemetery	9	1,278	Stewart anemometer	1/76- 9/77

Missing data--

Missing data are indicated by 9999.

Data Sample

The sample presented here is 12 records, 60 to 71 of the 8,404 records included in data set C7A1.

1234567890123456789012345678901234567890123456789012345678901234567890															
151	32F02176	13012	1	46	32	33	34	33	18	25	33	28	31	48	38
151	32F02176	13100	1	29	26	47	50	57	67	59	58	62	65	67	61
151	32F02176	13112	1	43	60	45	51	74	95	86	93	90	93	76	72
151	32F02176	2 100	1	74	68	80	85	94	126	92	109	115	128	99	105
151	32F02176	2 112	1	99	91	97	96	78	68	85	76	65	61	57	50
151	32F02176	2 200	1	52	54	54	46	38	43	43	48	52	46	38	27
151	32F02176	2 212	1	41	49	48	40	44	40	50	66	62	64	65	75
151	32F02176	2 300	1	80	73	55	67	51	57	64	35	44	65	60	66
151	32F02176	2 312	1	88	78	68	55	49	26	22	47	78	89	70	78
151	32F02176	2 400	1	73	71	74	79	90	100	69	75	67	62	54	55
151	32F02176	2 412	1	44	45	45	34	21	41	47	41	33	28	37	41
151	32F02176	2 500	1	32	40	32	27	33	37	49	38	39	32	29	43

Quality Assurance

Objectives--

The purpose of the study was to provide data for understanding the patterns of atmospheric dispersion in the vicinity of the Columbia Generating Station. This data set documents wind speed, which, together with the wind direction data (data set C7A2), provides an estimate of the speed and direction of the transport of materials from the generating station through the atmosphere.

Monitoring Sites--

This study required that at least one site be relatively unaffected by the generating station and that the data for atmospheric dispersion measurements be valid between stack height and the plume rise. Wind records for Madison, WI show that easterly winds are relatively infrequent; thus, a site directly west of the generating station would be influenced the least by the generating station. The necessity of knowing the dispersion characteristics of the atmosphere between the top of the stack and the plume rise required measurements between 166 and 333 m above the generating site. Accordingly, the Messer site was established 7.1 km west of the power plant on the Baraboo Hills at an elevation of 390 m above MSL (Figure 13). The primary objective for this site was to obtain meteorological measurements at approximately the same height as the 150 m stack of the power plant. Because elevation of the Messer site is 120 m above the Columbia Generating site, a 32-m tower was erected to place the instruments at about the level of the stack top. The site was located at the northern edge of a farm field and was well exposed to the wind from all directions. The local area is characterized by open forest broken by farm fields. The Baraboo Hills continue to rise to the west of the Messer site, while the bluffs drop sharply to the Wisconsin River valley < 500 m to the north and east of the site.

In addition to this primary monitoring station at Messer, three satellite monitoring stations were established at points encircling the generating station: Wyocena to the east, Dekorra to the southwest, and Cemetery to the northwest. The instrumentation at these three sites was not as complete as at the Messer site. The data collection at these sites was intended to corroborate the Messer data and to provide an understanding of variation caused by topographical differences and differences in direction relative to the generating station.

The Wyocena site was located about 8.9 km to the east of the Columbia Generating Station at an elevation of 245 m. A 9-m tower was erected at this site with instrumentation to measure wind speed and direction. The site was well exposed except for a stand of trees about 150 m to the east. The flat terrain is characterized by open grasslands.

The Dekorra site was located 4.2 km southwest of the power plant and only 4 km from the eastern base of the Baraboo Hills at an elevation of

245 m. A 9-m tower was located 100 m east of a rather dense stand of trees 10 to 15 m high. Exposure to the wind was quite good in directions other than the west. The area surrounding the site is characterized by open forest and is more rolling than the other valley sites.

The Cemetery site was located just to the north of Portage, WI and 9.7 km north of the power plant at an elevation of 250 m. A 9-m tower was located on a small knoll that provided excellent exposure to the wind. The only obstruction was a small stand of 10-m high trees at a distance of 150 m to the south of the tower. The terrain, consisting mostly of open forest, was quite flat away from the site.

Monitoring Equipment and Procedures--

At all four sites, wind speed was measured by Stewart four-cup anemometers. Readings were included for two Stewart anemometers at the Messer site (monitoring different heights) and one Stewart anemometer at each of the other sites. On each anemometer, the 0.8 km (0.5 mile) contact was used to operate an event marker on an Esterline-Angus Model AW 0 to 1 mA galvanometer recorder so that the number of contacts in a 30-min. period corresponded to the average wind speed in mph for the 30-min. period. A pulse amplifier at each site operated the event marker. These pulse amplifiers, which were built by the researchers, had a range of 0 to 12 v and supplied 0 to 1.4 v to the anemometers. In order to eliminate errors of measurement due to voltage variation, zero and full scale readings from the pulse amplifiers were taken at the beginning and end of each chart roll. Once per week, the chart rolls were changed and the instruments checked and required adjustments or repairs were made.

For the Stewart anemometers, the manufacturer specified an accuracy of ± 0.5 mph. The response threshold of the anemometers was between 0.5 and 1.0 m/sec. Individual anemometers were assumed accurate to ± 0.5 m/sec, but no further assumptions were made concerning the comparison of anemometers between sites.

At the Messer site, an additional wind-speed monitoring system at 32 m, consisted of a Beckman-Whitley Type F anemometer and an Esterline-Angus Model AW recorder. The Beckman-Whitley anemometer provided an important additional type of measurement--instantaneous wind speed--supplementing the Stewart anemometers. The three-cup Beckman-Whitley anemometer turned a slotted disk which permitted light from a bulb to fall on a photo tube. The detected light-pulse repetition rate was a measure of the rate at which the anemometer was turning. There were 180 slots in the disk providing virtually a continuous record, so that even in light winds the pulse repetition rate was adequate. The pulse went to a frequency-to-voltage converter and was recorded on an Esterline-Angus Model AW recorder. Full scale output of the recorder was a maximum of 27 m/sec. The overall system error for this anemometer system is $\pm 4\%$ of full scale or ± 1.2 m/sec, according to the manufacturer's specifications. The exponential response time is about 2 sec.

Initially, two Stewart four-cup anemometers were set up at each of the Wyocena, Dekorra, and Cemetery sites so that a dual system was established at each of the four sites. In processing, occasional checks were made between the two sets of records in data reduction but only one set was actually processed since they usually were in agreement. When the records indicated that one anemometer was not working, the other set of records was used.

Data Reduction--

Data processing involved the following steps: the timing of charts, conversion of chart data to hourly averages, punching the data on computer cards, checking the data for errors, and conversion to scientific units (m/sec). The number of contacts (of the anemometer cups) in 1 hr corresponds to the average wind speed in mph. Once the charts were timed, the output of the Esterline-Angus recorders, indicating the number of contacts, was translated to punch cards on an IBM 020 keypunch by means of a program developed by Stearns (1960).

Data Recoveries--

Table 16 lists the data recovery percentage for each measurement during the entire period for which there are records. Data recovery is computed based on the total number of possible observations during the data collecting period for each anemometer.

TABLE 16. DATA RECOVERIES FOR DATA SET C7A1

Parameter code number	Site	Height of measurement (m)	No. of possible observations	Data recovery (%)
32	Messer	32	17,544	79.50
34	Messer	32	17,544	83.37
35	Messer	2	17,544	88.81
43	Wyocena	9	15,336	94.83
53	Dekorrra	9	17,544	90.34
63	Cemetery	9	15,336	89.51

Investigators--

This investigation was conducted under the supervision of Charles R. Stearns, by Phillip Falconer, George Weidner, Eric Hennen, Brent Bowen, and Leonard Dzamba. At the time of the investigation, they were working toward M.S. degrees in Meteorology at the University of Wisconsin-Madison.

Supporting Documents

Bowen, Brent. 1977. Ozone renewal near the ground due to intermittent meteorological events. M.S. Thesis, University of Wisconsin-Madison.

Falconer, Phillip. 1973. A pilot diffusion climatology survey for a power generating site near Portage, Wisconsin. M.S. Thesis, University of Wisconsin-Madison.

Meteorology. In: Documentation of environmental change related to the Columbia Electric Generating Station. Institute for Environmental Studies, Reports 58, 62, 66, 69, 82, 92, University of Wisconsin-Madison.

Stearns, C.R., L. Dzamba, and Brent Bowen. In press. Instrumentation, recording, and processing of meteorological data near Portage, Wisconsin, U.S. Environmental Protection Agency, Cincinnati, Ohio.

Weidner, George. 1976. Topographic influence on surface wind near Portage, Wisconsin. M.S. Thesis, University of Wisconsin-Madison.

DATA SET C7A2: WIND DIRECTION MONITORING NEAR THE COLUMBIA GENERATING STATION (1976-77)

Data Summary

Abstract--

This data set contains hourly average records of wind direction (in degrees) from measurement systems at four monitoring sites located 4.2 to 9.7 km from the Columbia Generating Station. Wind direction was monitored at a height of 9 m at the Wyocena, Dekorra, and Cemetary sites and at a height of 32 m at the Messer site.

Dates of Research--

1976-77.

Data Form--

Computer file containing 10,960 units with one card-image/unit.

Data Format

Field Description--

The following field description is a modified version of the Storage and Retrieval of Aeromatic Data (SAROAD) format developed by the U.S. Environmental Protection Agency.

Column	Format	Description
1	I1	Card format identification; 1=multiple
2-3	I2	State code; 51=Wisconsin
8-10	I2	Parameter code (31, 33, 41, 42, 51, 52, 61, 62) ⁸
11	A1	Agency type; F=state agency
12-13	I2	Project classification; 02=source oriented ambient surveillance
14	I1	Sampling time interval; 1=1 hr
15-16	I2	Year
17-18	I2	Month
19-20	I2	Day
21-22	I2	Sampling start hour; 0=midnight, 12=noon
32	I1	Decimal locator: indicates number of digits from the right for placement of decimal point
33-80	I2I4	Observations (in degrees), 0=North with a clockwise increment

TABLE 17. MEASUREMENTS INCLUDED IN DATA SET C7A2

Parameter code number in field description	Site	Height of measurement (m)	No. of units in file	Sensor	Dates
31	Messer	32	1462	Beckman-Whitley	1/76-12/77
33	Messer	32	1462	Wind vane	1/76-12/77
41	Wyocena	9	1278	Wind vane	1/76- 9/77
42	Wyocena	9	1278	Wind vane	1/76- 9/77
51	Dekorra	9	1462	Wind vane	1/76-12/77
52	Dekorra	9	1462	Wind vane	1/76-12/77
61	Cemetery	9	1278	Wind vane	1/76- 9/77
62	Cemetery	9	1278	Wind vane	1/76- 9/77

Missing Data--

Missing data are indicated by 9999.

⁸Each parameter code number identifies a measurement within this data set (see Table 17).

Data Sample

The sample presented here is 16 records, 1 to 16 of the 10,960 records included in data set C7A2.

1234567890123456789012345678901234567890123456789012345678901234567890																	
151	31F02176	1	100		0	39	31	28	38	30	37	34	49	54	69	79	81
151	31F02176	1	112		0	79	77	80	78	82	91	111	117	126	132	136	141
151	31F02176	1	200		0	137	140	143	148	150	158	168	185	198	205	206	208
151	31F02176	1	212		0	211	209	207	212	232	234	236	241	237	251	257	259
151	31F02176	1	300		0	272	266	253	254	259	263	260	268	267	268	269	272
151	31F02176	1	312		0	273	274	278	279	291	295	294	289	292	289	286	283
151	31F02176	1	400		0	281	283	282	280	276	277	274	273	275	282	284	276
151	31F02176	1	412		0	276	272	268	275	273	261	243	228	230	219	185	184
151	31F02176	1	500		0	189	189	182	171	172	164	158	155	152	155	156	163
151	31F02176	1	512		0	166	170	172	167	163	162	161	166	169	172	169	166
151	31F02176	1	600		0	164	163	162	160	162	163	163	164	162	169	178	176
151	31F02176	1	612		0	172	166	168	170	176	229	250	262	276	298	323	356
151	31F02176	1	700		0	355	358	358	358	319	319	315	319	319	315	313	310
151	31F02176	1	712		0	310	315	312	292	295	292	295	290	286	287	288	283
151	31F02176	1	800		0	276	269	268	262	255	249	999	999	999	999	999	999
151	31F02176	1	812		0	999	999	999	999	999	999	999	999	999	999	999	999
Quality Assurance																	

Quality Assurance

Objectives--

The purpose of this study was to provide a basis for understanding the patterns of atmospheric dispersion in the vicinity of the Columbia Generating Station. This data set documents wind direction, which, together with the wind speed data (data set C7A1), provides an estimate of the speed and direction of the transport of materials from the generating station through the atmosphere.

Monitoring Sites--

Same as data set C7A1.

Monitoring Equipment and Procedures--

A dual wind-direction monitoring system was set up at all four sites. The majority of the systems consisted of wind vanes made available by the Mechanical Engineering Central Service Shop of the University of Wisconsin-Madison. Two of these wind vanes were set up at a height of 9 m at each of the three sites--Wyocena, Dekorra, and Cemetery--providing a dual system. One of these UW wind vanes was set up at the 32-m height at the Messer site; the second system was a Beckman-Whitley Type F wind vane.

The wind vanes made at the University of Wisconsin-Madison were vane position potentiometers of 1,000 Ω resistance. The output went directly to the Esterline-Angus recorders and was not linear with the input. The recorder resistance was 1,400 Ω . With 1.4 vac applied to the 1,000 Ω potentiometer the recorder indicates full-scale deflection for the maximum potentiometer position. The nonlinearity of the wind direction as a function of the recorder output is corrected in the data processing. The pulse amplifiers used to power the Stewart anemometers (see data set C7A1)

also supplied voltage to the wind vanes, providing a regulated power supply. Tests showed that the power supply output voltage was constant for an input voltage range of 70 to 140 vac.

The Beckman-Whitley Type F wind vane was also a vane-positioned potentiometer. The amplification was suitable for the output to be linear with respect to the input. This wind vane covered a range of 345° with a 15° dead zone. The dead zone was produced in recording when the marker had to move from 0° at one side of the chart to 345° at the other side. The result is a wind direction error of $\pm 15^\circ$.

Although the initial orientation of the two wind vanes at each site was the same, between January and August 1976 the orientation was changed so that the difference between the readings of the two vanes in each dual system was reduced from about 20° to about 5° . For each pair of wind vanes the dead zones of the potentiometers were oriented 180° out of phase with respect to each other so that the potentiometer output was zero when the vanes pointed toward each other. After the vanes were in position on the towers, the direction of the zero was measured by a Brunton compass.

The advantage of this dual-system method is that, when one wind vane is in the dead zone and the recorder is swinging from zero to full scale, the second wind vane is recording near mid-scale and the data can be recovered. In data processing, the recordings from the two vanes were converted to the same compass orientation so that cross-checking is possible. This system improved the absolute value of the wind direction. However, the vanes still indicated different values for a given time period. Part of the discrepancy between the vanes was due to interactions between the wind and the tower structure. Where there is a discrepancy, the most reliable wind direction value should be the average of the two vanes.

The chart speeds for the Esterline-Angus Model AW strip-chart recorder were all synchronized at 3 inch/hr. Once per week the sites were checked and the required instrument adjustments or repairs were made.

Data Reduction--

The Beckman-Whitley wind vane measures the horizontal wind direction by mechanically rotating a wiper arm on the potentiometer. The voltage output is recorded directly.

For the UW wind vanes, voltage output is not recorded directly. An equation is used to transform the data. The equation measures the arc recorded and then, determining the angle shown, converts the data to direction in degrees. (Refer to data set C7A1 for a description of data processing.)

Data Recoveries--

Table 18 lists the data recovery percentage for each measurement during the entire period for which records exist. The data recovery figures shown in Table 18 are improved when records from duplicate monitors are cross-

checked, since one instrument might have been operating when the other monitor was not recording properly. Data recovery is computed for each file based on the total number of possible observations during the monitoring period.

TABLE 18. DATA RECOVERIES FOR DATA SET C7A2

Parameter code number in field description	Site	Height of measurement (m)	No. of possible observations	Data recovery (%)
31	Messer	32	17,544	90.14
33	Messer	32	17,544	86.09
41	Wyocena	9	15,336	88.20
42	Wyocena	9	15,336	77.22
51	Dekorrra	9	17,544	97.97
52	Dekorrra	9	17,544	89.67
61	Cemetery	9	15,336	78.06
62	Cemetery	9	15,336	81.13

Investigators--

Same as data set C7A1.

Supporting Documents

Same as data set C7A1.

DATA SET C7A3: AIR TEMPERATURE GRADIENTS AT THE MESSER MONITORING STATION (1976-77)

Data Summary

Investigators--

P. Falconer, G. Weidner, E. Hennen, B. Bowen, L. Dzamba, and C. R. Stearns.

Abstract--

This data set contains hourly average records of air-temperature differences ($^{\circ}\text{C}$) among five pairs of measurement points located at varying heights at the Messer site located 7.1 km from the Columbia Generating Station. These records, converted to gradients, provide a measurement of

the static stability of the atmosphere between a series of measurement points.

Dates of Research--

1976-77.

Data Form--

Computer file containing 4,860 units with one card-image/unit.

Data Format

Field Description--

The following field description is a modified version of the SAROAD format developed by the U.S. Environmental Protection Agency.

<u>Column</u>	<u>Format</u>	<u>Description</u>
1	I1	Card format identification: 1=multiple
2-3	I2	State code: 51=Wisconsin
8-10	I2	Parameter code (3,4,5,6,9) ⁹
11	A1	Agency type: F=state agency
12-13	I2	Project classification: 02=source-orientated ambient surveillance
14	I1	Sampling time interval: 1=1 hr
15-16	I2	Year
17-18	I2	Month
19-20	I2	Day
21-22	I2	Sampling start hour; 0=midnight, 12=noon
32	I1	Decimal locator; indicates number of digits from the right for placement of decimal point
33-80	I2I4	Observations

TABLE 19. MEASUREMENTS INCLUDED IN DATA SET C7A3

Parameter code number in field description	No. of units in file	Location
3	972	0.2 to 2 m
4	972	2 m to inside shelter
5	972	2 to 32 m
6	972	soil (10 cm) outside to inside shelter
9	972	2 to 8 m

⁹Each parameter code number identifies a measurement within this data set (see Table 19).

Missing Data--

Missing data are indicated by 999.

Data Sample

The sample presented here is 12 units, 1 to 12 of the 4,860 units included in data set C7A3.

123456789012345678901234567890123456789012345678901234567890

151	3F02176	1	100	2	22	19	38	15	14	14	17	16	14	15	3	-8
151	3F02176	1	112	2	-19	-23	-33	-16	-12	-8	-2	8	28	17	13	11
151	3F02176	1	200	2	-5	-3	-4	-5	-11	-15	-6	-5	-5	16	35	15
151	3F02176	1	212	2	8	-15	-18	-17	-13	-9	1	0	-2	-3	-1	-7
151	3F02176	1	300	2	3	1	1	-2	-3	-4	-1	0	0	-2	-9	-26
151	3F02176	1	312	2	-51	-49	-51	-55	-33	-27	-6	-3	1	0	8	9
151	3F02176	1	400	2	2	4	7	6	4	7	8	4	-14	-42	-58	-66
151	3F02176	1	412	2	-64	-63	-40	4	36	84	107	122	150	152	54	45
151	3F02176	1	500	2	36	25	27	-32	-27	-8	-4	4	-6	-61	-71	-94
151	3F02176	1	512	2	-74	-50	-28	12	57	51	48	46	40	32	28	21
151	3F02176	1	600	2	20	18	15	14	15	12	14	13	6	-14	-10	-2
151	3F02176	1	612	2	-23	-31	-18	-17	-10	-4	-3	-2	-1	-3	-6	-7

Quality Assurance

Objectives--

The objectives for this data set are similar and complementary to those for data sets C7A1 and C7A2 since all three data sets help provide a basis for understanding the patterns of atmospheric dispersion in the vicinity of the Columbia Generating Station and the structure of the transport system by which materials from the generating station were dispersed in the atmosphere. The specific objective of this data set was to measure the static stability of the atmosphere between pairs of measurement points.

Monitoring Sites--

The monitoring was carried out at the Messer site located 7.1 km from the Columbia Generating Station (see data set C7A1).

Monitoring Equipment and Procedures--

Ventilated and shielded two-junction thermocouples with a 2-min. time constant built by the investigators were used to measure vertical air temperature differences. The copper constantan wires were housed in aluminum probes, secured with an adhesive sealant and enclosed within a highly polished, ventilated duct. The two-junction thermocouple has a signal of 0.08 mv for a temperature differences of 1°C between the junctions. The generated voltage output was fed directly to a 0-2.5 mv Brown strip chart recorder. The system accuracy was $\pm 0.1^\circ\text{C}$ corresponding to 10 mv noise. The thermocouple ducts were open to the north in an attempt to limit solar heating.

Air temperature gradients were monitored outdoors between paired measurement points. There were three pairs of height points: 0.2 to 2.0 m, 2 to 32 m, and 2 to 8 m. As reference measurements, gradients were also monitored between height points at 2 m outside to 2 m inside the shelter housing the recording equipment and the soil outside to 2 m inside the shelter. The shelter was a 2.1 x 2.7 x 2.1 m hut situated 91.4 m from the tower on the northeast corner of the Messer monitoring site. The temperature inside the shelter was controlled so that measurements obtained inside the shelter could be used to construct the absolute temperature of the air and to serve as a control for other measurements. The readings inside the shelter were obtained by placing the sensor in a pot of oil situated approximately 2 m above the ground. The oil provided a more gradual temperature adjustment for the sensor. The shelter measurements did not monitor vertical gradients as did the other three measurements.

The thermocouples were checked once a year. Both ends were set in a water bath and checked against each other. Once per week the site was checked and the required instrument adjustments or repairs were made.

Data Reduction--

A Digi Grid System, manufactured by Computer Equipment Corporation was used for digitizing the strip charts from the Brown recorder point by point. Values were recorded at 5 min. intervals on the strip chart. These values were used to obtain hourly averages in data reduction.

Data Recoveries--

Table 20 lists the data recovery percentage for each measurement during the entire period for which records exist. Data recovery is computed based on the total number of possible observations during the data period.

TABLE 20. DATA RECOVERIES FOR DATA SET C7A3

Parameter code no. in field description	Location	No. of possible observations	Data recovery (%)
3	0.2 to 2 m	11,664	87.16
4	2 m to inside shelter	11,664	85.06
5	2 to 32 m	11,664	86.11
6	Soil (10 cm) outside to inside shelter	11,664	87.81
9	2 to 8 m	11,664	85.54

Investigators--

Same as data set C7A1.

Supporting Documents

Same as data set C7A1.

DATA SET C7A4: SOLAR RADIATION MONITORING NEAR THE COLUMBIA GENERATING STATION (1976-77)

Data Summary

Investigators--

P. Falconer, G. Weidner, E. Hennen, B. Bowen, L. Dzamba, and C. R. Stearns.

Abstract--

This data set contains hourly average records of (1) net radiation (the radiation coming in on a flat surface) and (2) solar radiation (net radiation minus what is reflected up) obtained at the Messer site located 7.1 km from the Columbia Generating Station. Solar radiation includes both shortwave and longwave radiation. These measurements, in Langleys/min., provide an estimate of the solar radiation at the surface of the earth, which affects the heating of the ground and the air.

Dates of Research--

1976-77.

Data Form--

Computer file containing 1,944 units with one card-image/unit.

Data Format

Field Description--

The following field description is a modified version of the SAROAD format developed by the U.S. Environmental Protection Agency.

<u>Column</u>	<u>Format</u>	<u>Description</u>
1	I1	Card format identification: 1=multiple
2-3	I2	State code: 51=Wisconsin
8-10	I2	Parameter: 2=solar radiation, 8=net radiation
11	A1	Agency type: F=state agency
12-13	I2	Project classification: 02=source-oriented ambient surveillance
14	I1	Sampling time interval: 1=1 hr
15-16	I2	Year
17-18	I2	Month

Day
Sampling start hour: 0=midnight, 12=noon
Decimal locator
Observations (Langley/min.)

Missing Data--

Missing data are indicated by 999.

Data Sample

The sample presented here is 12 records, 1 to 12 of the 1,944 records included in data set C7A4.

[illegible]

Quality Assurance

Objectives--

The purpose of this study was to determine the solar radiation at the surface of the earth near the Columbia Generating Station. This information was needed for the air pollution model since solar radiation affects the heating of the ground and the air. Solar radiation data also contribute to identifying climatological trends and to determining possible climatic effects of the generating station and its cooling lake.

Monitoring Site--

The monitoring was carried out at the Messer site located 7.1 km from the Columbia Generating Station (see data set C7A1 for a complete description).

Monitoring Equipment and Procedures--

Two types of measurement were carried out:
(1) Net radiation, the

(1) Net radiation, the radiation coming in on a flat surface, was monitored with a ventilated net radiometer of the type described by Suomi et al. (1954), built by the investigators. The instrument was supported on a tripod situated on the ground 10 m away from the tower.

(2) Solar or global radiation, the radiation coming in on a flat surface, including shortwave and longwave minus what is reflected up, was monitored with an Eppley 10-junction pyranometer. The instrument was located on top of the recording shelter (2.3 m above the ground) free from blockage of direct sunlight by any of the other measuring systems.

A 12-channel Brown strip chart recorder of ± 2.0 mv range was used to record the signals from the two radiation sensors. Once a week the site was checked and the required instrument adjustments or repairs were made.

Calibration--

The ventilated net radiometer and the Eppley pyranometer were calibrated every 6 months by checking them against each other. On making the checks, the beam radiation on both instruments was shaded and compared. If the two instruments were in proper calibration, both showed the same reading. All the tests were within the 10% limit.

Data Reduction--

The readings, obtained for 5 min. intervals, were converted to Langley/min. Hourly averages were calculated and recorded.

Data Recoveries--

Table 21 lists the data recovery percentage for each measurement during the entire period for which records exist. Data recovery is computed based on the total number of possible observations during the data period.

TABLE 21. DATA RECOVERIES FOR DATA SET C7A4

Parameter code number in field descriptions	Parameter	Dates	No. of possible observations	Data recovery (%)
2	Solar radiation	1/76 to 4/77	11,664	89.27
8	Net radiation	1/76 to 4/77	11,664	84.95

Investigators--

Same as data set C7A1.

Supporting Documents

Same as data set C7A1.

DATA SET C7A5: RAINFALL MONITORING AT FOUR SITES NEAR THE COLUMBIA
GENERATING STATION (1972-76)

Data Summary

Investigators--

P. Falconer, G. Weidner, E. Hennen, B. Bowen, L. Dzamba, and
C. R. Stearns.

Abstract--

This data set contains records of rainfall at four observation sites near the Columbia Generating Station. The Messer site is located 7.1 km west, the Wyocena site 8.9 km east, the Dekorra site 4.2 km southwest and the Cemetery site 9.7 km north of the power plant. Specifically, the starting and stopping times for each rainfall event and the amount of rain (in inches) were recorded. Monitoring was carried out from 1972 to 1976 at the Messer site and between 1974 and 1976 at the Cemetery, Wyocena, and Dekorra sites. The monitoring covered only the months from April through October, and monthly summaries are included.

Dates of Research--

1972-76.

Data Form--

Computer file containing 810 units with one card-image/unit.

Data Format

Field Description--

For each month the file contains a number of daily record cards followed by a monthly summary card.

Daily Record Card

<u>Column</u>	<u>Format</u>	<u>Description</u>
1-2	I2	Year
3-4	I2	Month
5-6	I2	Day
7-8	I2	Site code; Messer=30, Wyocena=40, Dekorra=50, Cemetery=60
9-11	I3	Start time of precipitation event (to nearest 10 min)
12-14	I3	End time of precipitation event (to nearest 10 min)
15-17	F3.2	Amount of rain (inches)
18-80	F3.2	Start time, end time and amount of rain (repeated as needed)

Monthly Summary Card

1-2	I2	Year
3-4	I2	Month
7-8	I2	Site code; Messer=30, Wyocena=40, Dekorra=50, Cemetery=60
77-80	F3.2	Amount (inches)

Missing Data--

Not applicable.

Data Sample

The sample presented here is 15 records, 22 to 36 of the 810 records included in data set C7A5.

1234567890123456789012345678901234567890123456789012345678901234567890

72100630013035016
72101030233240004
72101130000010005023024001
72102030181240044
721021300000052021064065001083120008223234003
72102230002003010042043001053173099184190006202234020
72102330061240012
7210 30
72110630194201003213214001232233002 0251
72110730001200050430550015
72111530103104003
7211 30
73042930050073047083100004143153006170200022210220016 0074
73043030003040018180193019203210002220233008
7304 30 0142

Quality Assurance

Objectives--

This study monitored rainfall, to assess the possible relationship between this parameter and the ground-level concentration of material from the smoke stack. Also, this study was designed to identify any increased precipitation resulting from the introduction of condensation and water vapor from the stack of the generating station.

Monitoring Sites--

There was one set of monitoring equipment at each of the four sites-- Messer, Dekorra, Wyocena, and Cemetery. In relation to the Columbia Generating Station, Messer was located 7.1 km west, Dekorra was 4.2 km southwest, Wyocena was 8.9 km east and Cemetery was 9.7 km north. (For a description of these sites, see data set C7A1.)

Monitoring Equipment and Procedures--

Rainfall was monitored at each of the four sites with a tipping bucket rain gauge and a Weather Measure Corporation Model P521 event recorder. The start and stop times for each storm event and the amount of precipitation were recorded. The tipping-bucket rain gauges each detected 0.01 inch of rain entering the tipping mechanism below the exposed orifice. The number of tips was recorded and used to determine the rainfall for each tip. The signals were sent to an event marker on a Weather Measure Model P251 event recorder. The drum-type event recorder made 1 revolution/week. The advantage of using this method for recording rainfall is that the start and stop times of each rainfall event can be determined. The rain gauges were not equipped with heaters for winter use and were operated only from April through October.

Each rain gauge was calibrated by slowly pouring in a known amount of water and adjusting the gauges. These instruments were calibrated once on 12 April 1976 and meter corrections were as follows Messer 0%; Wyocena +2%; Dekorra +22%; Cemetery +15%. The Dekorra and Cemetery data were adjusted for their respective error factors during tabulations of the data from the original records.

Data Reduction--

For the monthly summary, the total monthly rainfall is the total excluding any that might have fallen when the gauge was not operating correctly. Incorrect operation was due primarily to the ink running out or a malfunction caused by mice. Another sign of incorrect recordings was disagreement among the four rain gauges, one at each site. If three showed rainfall and a fourth monitor did not, the disagreeing monitor was assumed to be incorrect and these data were not included in the monthly summary.

Investigators--

Same as data set C7A1.

Supporting Documents

Same as data set C7A1.

DATA SET C7B1: INVERSION-LAYER MONITORING NEAR THE COLUMBIA GENERATING STATION (1976-77)

Data Summary

Investigators--

G. Weidner, E. Hennen, B. Bowen, L. Dzamba and C. R. Stearns.

Abstract--

This data set contains hourly average records of five types of measurements that were used to determine the height of the inversion layer in the atmosphere: sodar lowest base, sodar lowest top, sodar higher base, sodar higher top, and sodar thermal height. All measurements were obtained at the Cemetery site located 9.7 km from the Columbia Generating Station.

Dates of Research--

Feb.-Sept. 1977.

Data Form--

Computer file containing 4,674 units with one card-image/unit.

Data Format

Field Description--

The following description is a modified version of the SAROAD format developed by the U.S. Environmental Protection Agency.

<u>Column</u>	<u>Format</u>	<u>Description</u>
1	I1	Card format identification; 1=multiple
2-3	I2	State code; 51=Wisconsin
8-10	I2	Parameter code (65,66,67,68,69) ¹⁰
11	A1	Agency type; F=state agency
12-13	I2	Project classification; 02=source-oriented ambient surveillance
14	I1	Sampling time interval, 1=1 hr
15-16	I2	Year
17-18	I2	Month
19-20	I2	Day
21-22	I2	Sampling start hour; 0=midnight, 12=noon
32	I1	Decimal locator
33-80	I4	Observations (m)

Missing Data--

Missing data are indicated by 9999.

¹⁰Each parameter code number identifies a type of measurement within this data set (see Table 22).

TABLE 22. MEASUREMENTS INCLUDED IN DATA SET C7B1

Parameter code number in field description	No. of units in the file	Parameter	Dates
65	972	Sodar lowest base	2/76 to 4/77
66	972	Sodar lowest top	2/76 to 4/77
67	910	Sodar highest base	2/76 to 4/77
68	910	Sodar highest top	2/76 to 4/77
69	910	Height of thermal roof	2/76 to 4/77

Data Sample

The sample presented here is 12 records, 14 to 26 of the 4,673 records included in data set C7B1.

[illegible]

Quality Assurance

Objectives--

The purpose of this study was to monitor air inversion patterns in the vicinity of the Columbia Generating Station. This information was used to document the atmospheric transport system by which materials from the generating station were dispersed through the air. The height of the acoustic sounder return may be related to the mixing height of the atmosphere, the maximum height to which stack emission may be dispersed.

Monitoring Site--

The site was not located with regard to optimum meteorological conditions, but rather because of the availability of commercial power for the instrumentation and the willingness of someone to lease the land. The acoustic sounder was tried at the Columbia Generating Station site and at the Messer site and was finally situated at the Cemetery site located 9.7 km

north of the Columbia Generating Station (see data set C7A1 for a description of this site). The receiving antenna of the system was very sensitive to interference by extraneous sound at frequencies near 1,600 Hz; difficulties of this nature were experienced at the sites where the sounder was first tested. The sounder was moved to the Cemetery site where continuous measurements were possible, although there were still difficulties. The antenna of the acoustic sounder was protected from sources of extraneous noise by bales of hay. An enclosure was built for the acoustic sounder out of 8 ft high double-plywood boards. A 4-inch gap between the two layers of boards was lined with foam plastic.

Monitoring Equipment and Procedures--

An Aerovironment Model 300 acoustic sounder was used to obtain these data. A sound pulse 20 m/sec long at 1,600 Hz was transmitted vertically into the atmosphere. The air is stratified in shifting horizontal layers characterized by different temperature ranges. By monitoring the heights of regions where air temperature increases were occurring, the acoustic sounder tracked the changing location of air inversion layers.

The region reflecting the sound pulse had a top and bottom which were recorded as sodar base and top. Since two layers could reflect the sound pulse, records were obtained for the lower base and top and the higher base and top when two layers were present.

The acoustic sounder also tracked the thermal plume, which is composed of warm bubbles of air rising through the atmosphere. The reflected sound pulse indicates the upper boundary of this movement (the thermal roof) where the reflection ends.

The presence of a signal return was detected and recorded within a vertical range extending from 750 to 1,500 m above the ground. The time delay between the emitted and reflected pulses are recorded originally, and the delay time yields an estimate of the height of inversion layers and the height of the thermal roof in the atmosphere. The unit of measurement for these readings is meters, based on evaluating the interval between the emitted and reflected pulses in terms of the speed of sound. The hourly average values of the height of the inversion layer were estimated visually from the mass of original records.

Data Recoveries--

Table 23 lists the data recovery percentage for each measurement during the entire period for which records exist. Data recovery was computed based on total number of possible observations during the data period.

The sensitivity of the acoustic sounder presented problems for data recovery in terms of interference.

TABLE 23. DATA RECOVERIES FOR DATA SET C7B1

Parameter code number	Parameter	No. of possible observations	Data recovery (%)
65	Sodar lowest base	11,664	25.48
66	Sodar lowest top	11,664	25.33
67	Sodar highest base	10,920	25.05
68	Sodar highest top	10,920	24.68
69	Height of thermal roof	10,920	24.76

Investigators--

Same as data set C7A1.

Supporting Documents

Same as data set C7A1.

REFERENCE

Suomi, V. E., M. Fransilla, and N. F. Zstilzer. 1954. An economical net radiometer. J. Meteorol. 11:276-282.

SECTION 8

HYDROGEOLOGY

This subproject investigated the impact of the Columbia Generating Station on the ground-water system in the vicinity. Of special concern was the impact of the cooling lake on the existing ground-water regime, including its impact on the configuration of the ground-water flow system, on rates of flow, on water quality (thermal and chemical) and on water levels in the wetlands.

The principal goals of this subproject were: (1) to document changes in the groundwater system caused by the construction and operation of the Columbia Generating Station (2) and to develop quantitative techniques for simulating these impacts at other sites. All the data collected for this subproject applies to both goals. The second goal is documented in Andrews (1976, 1978).

Specific objectives for the data collected were: (1) to document the changes in groundwater flow direction and quantity, (2) to document the transfer of heat, a byproduct of the generating process, away from the site into the groundwater system, and (3) to document the impact of the generating process on the quality of the ground water in the vicinity of the site.

In relation to objective (1) one study was conducted. The data collected in this study are presented in data set C8A1. Data set C8A1 (Groundwater levels in 110 monitoring stations in the vicinity of the Columbia Generating Station (1971-77)) documents fluctuations in the upper boundary of the groundwater regime.

In relation to objective 2, four studies were conducted monitoring the movement of heat produced by the generating process into the ground-water system. The data collected in these studies are presented in data sets C8B1, C8B2, C8B3, and C8B4. Data set C8B1 (Temperature monitoring of 60 wells in the vicinity of the Columbia Generating Station (1973-75)) presents the results of a study that monitored temperatures at the bottom of wells which were open to the aquifer just below the water table. Data set C8B2 (Temperatures at different depths in a vertical plane west of the cooling lake (1976-78)) presents the results of a study which monitored temperatures at several depths in six wells such that the sampling points formed a vertical grid extending perpendicular to the west dike. Data set C8B3 (Temperatures in the vertical plane east and west of the cooling lake of the Columbia Generating Station (1977-78)) presents the results of a study that

monitored temperatures at several depths in 11 wells such that the monitoring points formed five vertical grids perpendicular to the east and west dikes. Data set C8B4 (Temperatures at two levels of the horizontal plane at 40 monitoring stations at the Columbia Generating Station (1977-78)) presents temperature readings at 0.5 and 1.5 m which were obtained on four occasions at 40 sampling points corresponding to the first stake in each of the first 40 transects established by the Wetlands Ecology-Plants subproject.

In relation to objective 3, one study was conducted monitoring the impact of the generating station on the quality of the groundwater in the surrounding area. The data collected in this study are presented in data set C8C1. Data set C8C1 (Quality of the ground water near the Columbia Generating Station (1972-77)) presents the results of analyzing water samples from 53 sampling stations.

In addition to the seven data sets described above, supplementary information concerning the monitoring points described in data sets C8A1, C8B1, C8B2, C8B3, and C8C1 also was obtained. These data are presented in auxiliary data set C8D1. Auxiliary data set C8D1 (Construction, location, and dimensions of the hydrogeology sampling points at the Columbia Generating Station site) presents background information concerning the observation wells that were used as the monitoring points for most of the studies conducted by the Hydrogeology subproject.

The investigators are David A. Stephenson, Professor; Mary Anderson, Associate Professor; Gregg Gibbs, Research Assistant; Neil Jacquet, Research Assistant; and Charles B. Andrews, Research Assistant; Department of Geology and Geophysics, University of Wisconsin-Madison. The report was compiled by Hilary McLellan, Data Analyst, Water Resources Center.

DATA SET C8A1: GROUND-WATER LEVELS IN 110 MONITORING STATIONS NEAR THE COLUMBIA GENERATING STATION 1971-77

Data Summary

Investigators--

G. Gibbs, N. Jacquet, C. Andrews, D. Stephenson, and M. Anderson.

Abstract--

This data set contains the results of a monthly survey conducted for 7 yr that monitored the upper level of the groundwater system around the Columbia Generating Station. Measurements were taken in 110 observation wells located 0 to 1,200 ft from the dike of the cooling lake at approximately monthly intervals.

Dates of Research--

5 December 1971-24 September 1977.

Data Form--

Computer file containing 683 units with one card-image/unit.

Data Format

Field Description--

<u>Column</u>	<u>Format</u>	<u>Description</u>
1-3	I3	Well number
7-8	I2	Month
9-10	I2	Day
11-12	I2	Year
15-20	F6.2	Well water level ¹¹
23-24	I2	Month
25-26	I2	Day
27-28	I2	Year
31-36	F6.2	Well water level
39-40	I2	Month
41-42	I2	Day
43-44	I2	Year
47-52	F6.2	Well water level
55-56	I2	Month
57-58	I2	Day
59-60	I2	Year
63-68	F6.2	Well water level

Missing Data--

No missing data. Unused data fields contain zero values.

Data Sample

The sample presented here is 15 records, 1 to 15 of the 683 records included in the complete data set C8A1.

123456789012345678901234567890123456789012345678901234567890

001	120571	782.82	010272	783.53	020372	783.25	030272	783.06
001	041572	783.21	042472	783.52	050372	782.60	061072	782.94
001	070372	782.46	080572	781.95	090972	783.26	100672	784.42
001	110372	784.31	120572	783.91	041773	788.52	052273	788.04
001	070573	787.51	080673	786.51	090773	784.06	100573	783.62
001	102773	783.36	113073	783.43	122173	783.04	011874	783.06
001	021874	783.08	033074	784.11	041774	783.92	050974	784.97
001	052474	784.11	053074	784.21	061074	784.88	062174	784.59
001	071374	784.73	082474	784.34	102074	783.27	111674	782.71
001	112474	782.85	121374	782.43	122074	782.17	010775	782.22
001	010775	782.22	020275	782.30	020275	782.30	022175	782.37
001	031175	782.46	032775	782.82	041575	783.78	051175	785.76
001	062575	787.15	070375	787.36	072575	787.27	082675	789.90
001	091475	778.30	092375	785.99	111575	785.53	020876	787.05
001	022676	787.25	030776	787.39	031476	787.39	041876	287.97

¹¹Water levels are indicated in feet above mean sea level.

Quality Assurance

Objectives--

The purpose of this survey was to document the impact of seepage from the cooling lake on ground-water levels in the surrounding area. In this study fluctuations in the upper boundary of the ground water system in the vicinity of the Columbia Generating Station (indicating fluctuations in ground water potential below the water table) were monitored, both before (5 Dec. 1971 to 13 June 1974) and after (14 June 1974 to 24 Sept. 1977) the cooling lake was filled.

Monitoring Sites--

Most of the sites are located within a few hundred feet of the dikes on the west side of the cooling lake and west and north of the ashpit (Figure 14). A few sites are located near the drainage ditch south of the cooling lake and five sites are situated next to the dikes on the south and east sides. There are two sites located approximately 631 ft east of the ashpit and three sites located approximately 1,200 ft from the cooling lake dike on the east side.

Monitoring Procedure--

Monitoring was carried out in 1.25-inch diameter galvanized iron pipe piezometer wells, each coupled to a 24-inch long sandpoint well tip. The sandpoints were constructed with 18-inch, 80 gauge screens to allow water to enter the well freely. Most piezometers were installed on the sand uplands with a truck mounted auger drill. Most wells were open to the aquifer just below the water table. After installation, the piezometers were hand pumped with a pitcher pump, and the piezometer tops were surveyed to the nearest 0.01 ft.

For each measurement a steel measuring tape calibrated to the nearest 0.01 ft was lowered down the wells to obtain water level readings. Measurements were made by an experienced field researcher.

Investigators--

This study was conducted successively by three researchers. Gregg Gibbs conducted the survey until 1 March 1973. At the time of the experiment, he was working toward an M.S. degree in Geology at the University of Wisconsin-Madison under the supervision of Professor D. Stephenson. From 2 March 1973 to Nov. 1974, the principal was Neil Jacquet, who at the time of the experiment was a graduate student at the University of Wisconsin-Madison. His work at the Columbia site was supervised by Professor D. Stephenson. The experiment was concluded after November 1974 by Charles B. Andrews, who at the time of the experiment was working toward a Ph.D. degree in Geology at the University of Wisconsin-Madison. His work was supervised by Professor D. Stephenson until January 1977, and then by Professor Mary Anderson. Field assistants helped with data collection throughout this study.

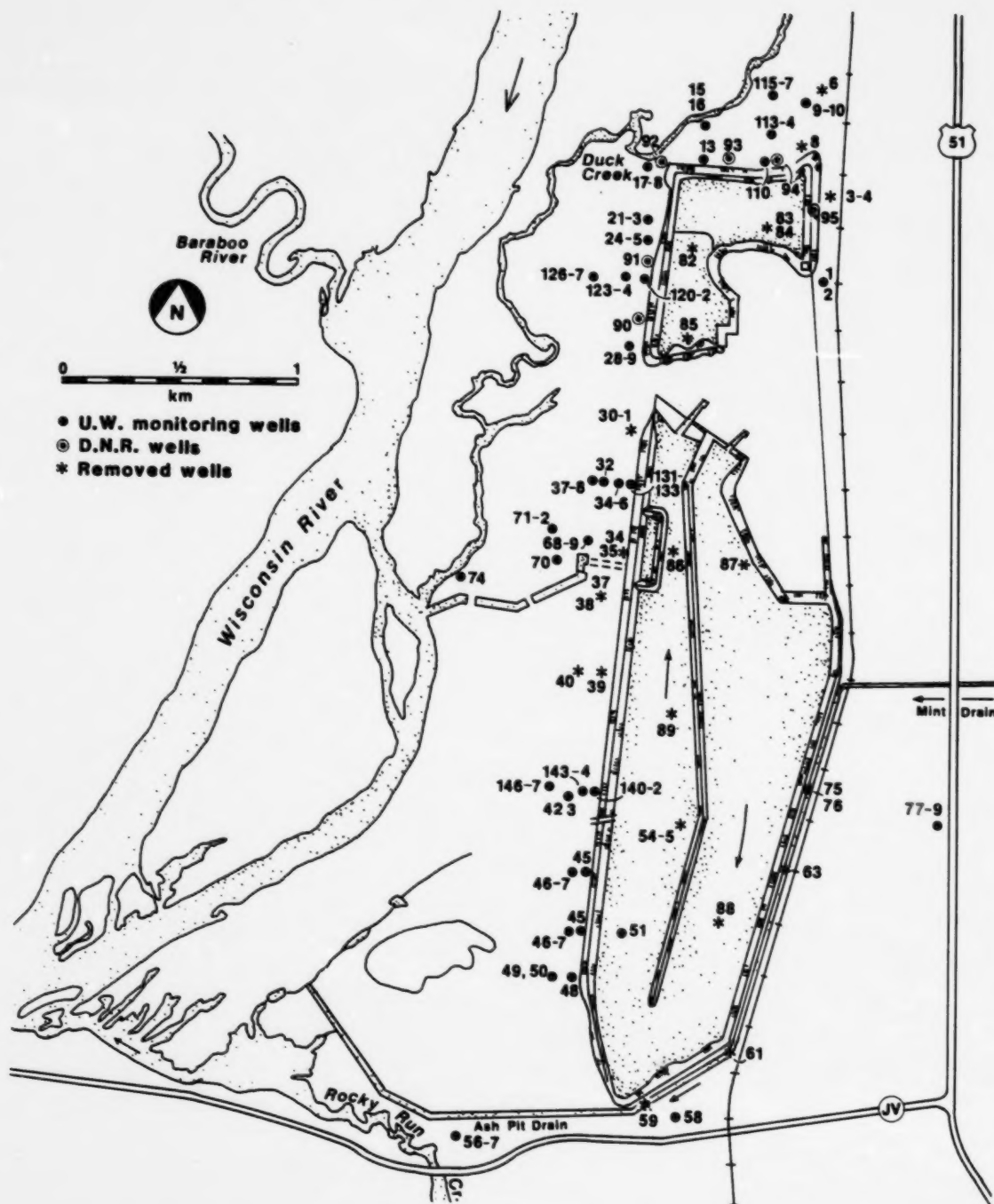


Figure 14. Hydrogeology monitoring stations around the cooling lake of the Columbia Generating Station.

Supporting Documents

Andrews, Charles B. 1976. An analysis of the impact of a coal-fired power plant on the groundwater supply of a wetland in central Wisconsin. M.S. Thesis. University of Wisconsin-Madison. 83 p.

Andrews, C.B., and M.P. Anderson. 1980. Impacts of coal-fired power plants on local ground-water systems. EPA-600/3-80-079. U.S. Environmental Protection Agency, Cincinnati, Ohio. 203 p.

Gibbs, Gregg. 1973. The hydrogeology of the Columbia Electric Generating Station site. M.S. Thesis. University of Wisconsin-Madison. 30 p.

Hydrogeology. In: Documentation of environmental change related to the Columbia Electric Generating Station. Institute for Environmental Studies, Reports 46, 58, 62, 66, 69, 82. University of Wisconsin-Madison.

DATA SET C8B1: TEMPERATURE MONITORING IN 60 WELLS IN THE VICINITY OF THE COLUMBIA GENERATING STATION 1973-75

Data Summary

Investigators--

G. Gibbs, N. Jacquet, C. Andrews, D. Stephenson, and M. Anderson.

Abstract--

This data set presents records of ground water temperatures ($^{\circ}\text{C}$) measured at the bottom of wells that were open to the aquifer just below the water table, forming a horizontal grid. Over a period of 5-yr, 5 to 25 readings were taken per well. This study provided a basis for simulating the response of ground water temperatures to seasonal changes in cooling lake temperatures.

Dates of Research--

6 August 1973-26 August 1975.

Data Form--

Computer file containing 132 units with one card-image/unit.

Data Format

Field Description--

<u>Column</u>	<u>Format</u>	<u>Description</u>
1-2	I2	Well number
4-5	I2	Month
6-7	I2	Day
8-9	I2	Year
11-15	F5.2	Temperature °C
17-22	3(I2)	Date
24-28	F5.2	Temperature °C
30-35	3(I2)	Date
37-41	F5.2	Temperature °C
43-48	3(I2)	Date
50-54	F5.2	Temperature °C
56-61	3(I2)	Date
63-67	F5.2	Temperature °C
69-74	3(I2)	Date
76-80	F5.2	Temperature °C

Missing Data--

No missing data. Unused data fields contain zero values.

Data Sample

The sample presented here is 10 records, 1 to 10 of the 132 units included in the complete data set C8B1.

1234567890123456789012345678901234567890123456789012345678901234567890

1	80673	6.67	90773	9.44	112973	6.67	122173	6.67	11874	9.44
1	21874	9.44	33074	9.44	41774	9.72	50974	9.44	61074	10.00
1	102074	12.50	112474	9.72	122074	9.89	41575	9.10	72575	11.00
1	82675	11.00	91475	10.00	0	0.	0	0.	0	0.
2	72575	11.00	91475	10.00	0	0.	0	0.	0	0.
3	122173	10.00	80673	14.17	90773	13.61	100573	10.56	112973	10.56
3	11874	9.17	21874	8.06	33074	7.22	41774	6.67	50974	6.39
4	61074	7.50	0	0.	0	0.	0	0.	0	0.
4	11874	7.50	21874	6.67	100573	12.50	112973	10.56	122173	9.17
4	33074	5.56	41774	5.56	50974	6.11	0	0.	0	0.

Quality Assurance

Objectives--

The purpose of this study was to document temperature changes in the ground-water system in response to seasonal changes in cooling lake temperatures. In this study ground water temperatures were monitored in a horizontal grid, at points just below the water table.

Monitoring Sites--

Same as data set C8A1.

Monitoring Procedures--

Monitoring was carried out in 1.25-inch diameter galvanized iron pipe piezometer wells, each coupled to a 24-inch long sandpoint well tip. The sandpoints were constructed with 18-inch, 80-gauge screens to allow water to enter the well freely. Most piezometers are in the wetlands; these were hand driven into place. A small number of piezometers were installed on the sandy uplands with a truck-mounted auger drill. All the wells were open to the aquifer just below the water table. After installation, the piezometers were hand pumped with a pitcher pump and the piezometer tops were surveyed to the nearest 0.01 ft.

A Yellow Springs Instrument Company Model 33 Salinity-Conductivity-Temperature Meter was used. This instrument combined a thermistor (temperature sensor) and meter in one assembly. The temperature sensor was lowered to the bottom of each well to obtain a reading. After November 1974 a vacuum pump was used to pump the wells until the temperature of the water being pumped was nearly constant before readings were taken. Accuracy of measurement was 0.1°C.

Calibration--

The Yellow Springs Instrument Company Model 33 Meter is calibrated by the manufacturer and is designed to remain permanently calibrated.

Investigators--

Same as data set C8A1.

Supporting Documents

- Andrews, Charles B. 1976. An analysis of the impact of a coal-fired power plant on the groundwater supply of a wetland in central Wisconsin. M.S. Thesis. University of Wisconsin-Madison. 83 p.
- Andrews, Charles B. 1978. The use of temperature to define groundwater systems. Ph.D. Dissertation. University of Wisconsin-Madison. 153 p.
- Andrews, C.B., and M.P. Anderson. 1980. Impacts of coal-fired power plants on local ground-water systems. EPA-600/3-80-079. U.S. Environmental Protection Agency, Cincinnati, Ohio. 203 p.
- Gibbs, Gregg. 1973. The hydrogeology of the Columbia Electric Generating Station site. M.S. Thesis. University of Wisconsin-Madison. 30 p.
- Hydrogeology. In: Documentation on environmental change related to the Columbia Electric Generating Station. Institute for Environmental

Studies, Reports 46, 58, 62, 66, 69, 82. University of Wisconsin-Madison.

DATA SET C8B2: TEMPERATURES AT DIFFERENT DEPTHS IN A VERTICAL PLANE WEST OF THE COOLING LAKE OF THE COLUMBIA GENERATING STATION (1976-78)

Data Summary

Investigators--

C. Andrews and M. Anderson.

Abstract--

This data set contains the results of an 18-month study that monitored (at different depths in the subsurface) the temperature in the ground water near the cooling lake. At approximately monthly intervals, water temperature ($^{\circ}\text{C}$) readings were obtained at 43 subsurface points in six wells that formed a vertical grid extending perpendicular to the west dike near the intake and outfall channels at the north end of the cooling lake. Seventy-four temperature readings were obtained for each monitoring point between Aug. 1976 and Jan. 1978.

Dates of Research--

August 1976-January 1978.

Data Form--

Computer file containing 547 units with one card-image/unit.

Data Format

Field Description--

<u>Column</u>	<u>Format</u>	<u>Description</u>
1-3	I3	Well number
5-8	F4.2	Depth of readings
10	I1	Reading type; 1=depth water temperature, 2=air temperature (depth=0.00), 3=cooling lake temperature
12-13	I2	Month
14-15	I2	Day
16-17	I2	Year
19-23	F5.2	Well temperature $^{\circ}\text{C}$
25-26	I2	Month
27-28	I2	Day
29-30	I2	Year
32-36	F5.2	Well temperature $^{\circ}\text{C}$

38-39	I2	Month
40-41	I2	Day
42-43	I2	Year
45-49	F5.2	Well temperature °C
51-52	I2	Month
53-54	I2	Day
55-56	I2	Year
58-62	F5.2	Well temperature °C
64-65	I2	Month
66-67	I2	Day
68-69	I2	Year
71-75	F5.2	Well temperature °C

Missing Data--

Missing data are indicated by 0.00. Unused data fields have zero values for sample month, day, and year.

Data Sample

The sample presented here is 10 records, 1 to 10 of the 547 units included in the complete data set C8B2.

1234567890123456789012345678901234567890123456789012345678901234567890

130	8.7	1	80776	22.68	81876	23.98	82076	24.13	82776	25.12	83076	25.58
130	8.7	1	91376	25.71	91776	27.15	102576	.00	102776	.00	110576	.00
130	8.7	1	111276	22.01	111576	21.53	112276	20.64	112976	19.22	120376	19.25
130	8.7	1	120776	17.73	121376	16.62	10677	10.06	11077	9.31	11377	8.78
130	8.7	1	11877	8.12	12677	7.58	13177	6.03	20277	7.32	20477	7.24
130	8.7	1	20777	7.11	20977	7.03	21177	.00	21477	6.75	21677	6.61
130	8.7	1	22177	.00	22377	.00	22877	6.09	30277	6.09	30777	6.19
130	8.7	1	31177	5.93	31477	5.71	31677	5.80	32177	5.90	32377	5.55
130	8.7	1	32877	.00	41577	.00	42177	5.08	42577	5.10	42777	4.87
130	8.7	1	50277	4.88	50477	4.79	50977	4.97	51677	5.84	51877	6.32

Quality Assurance

Objectives--

The objectives set are similar to the objectives for data set C8B1. Both studies were designed to monitor the flow of heat and water away from the dikes in order to document changes in temperatures due to seasonal changes in cooling lake temperatures. Data set C8B2 differs in that vertical, rather than horizontal, temperature flows were monitored. The entire flow of heat and water away from the dikes was assumed to occur in planes perpendicular to the plane of the dikes, and the flux of water and heat was modeled in several of these planes which represent 2-dimensional vertical cross-sections of the ground-water system. Results from each of the cross sections were combined to obtain the total flow of heat and water outward from the west dike of the cooling lake. Data set C8B2 presents the results of monitoring one vertical cross section.

Monitoring Sites--

The six monitoring wells were located in a line perpendicular to the west dike at progressively greater distances (Figure 14). Table 24 lists the distance from the dike of the sampling points and the depths at which measurements were obtained. The lake temperature was monitored adjacent to well 130. The air temperature was monitored in the area of the wells.

TABLE 24. LOCATION AND DEPTHS OF POINTS FOR MONITORING
GROUND-WATER TEMPERATURES WEST OF THE COOLING LAKE

Well number	Distance from dike (m)	Depth of measurements (m)
130	2	0.15, 0.91, 3.05, 6.1, 8.70
131	15	0.15, 0.91, 3.05, 4.57, 6.1, 9.15
132	3.25	0.15, 0.91, 3.05, 4.57, 6.1, 9.15
133	51	0.15, 0.91, 3.05, 6.1, 9.15
134	86	0.15, 0.91, 3.05, 6.1, 9.15
135	131.5	0.15, 0.91, 3.05, 6.1, 9.15

Monitoring Procedure--

Temperature readings were obtained with 42 thermistors (Yellow Springs Instrument Company Series 400), which were purchased as unmounted units. Between six and eight thermistors were positioned at different depths in the subsurface in each well. Each thermistor was soldered to three wires on a cable, two of the three wires were soldered to one lead, and the assembly was potted with silicon sealer inside a 0.64 x 5 cm piece of tygon tubing. Three wires were connected to each thermistor so that the lead wire resistance could be measured and subtracted from the resistance measured for the thermistor plus lead wire. The wires soldered to each thermistor were of sufficient length to reach the surface. All the thermistors to be placed in a well were bound together and wired to a connector that would remain at the surface when the thermistors were inserted in the well. A cable was wired from the thermistors at each of the six wells to a control box on the dike. The control box was equipped with a 48-position switch to allow access to each thermistor. The thermistors were placed in 10-m deep water-filled wells of 3.175 cm schedule-40 PVC pipe filled with glycerol. The pipes were jettied into place to minimize disturbance of subsurface materials. After the cables were placed in the wells, fiberglass insulation was stuffed into the remaining void space to minimize convection. Thermistors at depths of 0.1, 0.4, and 0.8 m were installed near the well rather than in the well. Air and lake temperatures also were monitored with the YSI 400 thermistors. The lake temperature reading was obtained by lowering the thermistor into the lake, and the air temperature reading was obtained after swinging the thermistor in the air. The investigators do not consider the air temperature data to be very reliable.

Analytical Procedure--

Resistance from the field measurements was coded, punched, cross-checked for errors, and converted to temperature by the following equation:

$$T^{-1} = A + B \log R + C(\log R)^3 \quad (1)$$

where the constants A, B, and C were determined from the thermistor calibration data, and T^{-1} is the inverse Kelvin temperature.

Critical Temperature Gradient--

The problem with taking readings at various depths in a well by lowering a thermistor down the well is that if the temperature gradient is above a critical value the temperature profile in the well will not correspond to the temperature profile in the subsurface materials. For a well with a diameter of 3.175 cm, the critical gradient is approximately 1°C/m at 10°C and 0.2°C/m at 25°C (Sammel 1968). The critical gradient was exceeded in many cases at the Columbia site. The error induced in the temperature readings was probably $< \pm 0.5^\circ\text{C}$ if the critical gradient was exceeded by less than 1 order of magnitude. Near the surface, where the gradient can be large, the induced error was greater.

Equipment--

From Aug. 1976 through Dec. 1976, all thermistor resistances were measured on a Shallcraft four-dial Wheatstone bridge with a 5-A full-scale needle galvanometer. Resistances could be read accurately to $\pm 3 \text{ X}$ at 4,000 Ω with this meter and probably had an operating accuracy of $\pm 10 \text{ X}$.

A Digitec digital-recording ohm meter mounted on a vehicle was used for measuring resistances from Jan. 1977 through Jan. 1978. The bulk of the resistance measures were made with this instrument, which had an operating accuracy of approximately $\pm 4 \Omega$ at 4,000 Ω . The Digitec meter operated in the field was a 12 VDC to 120 VAC square wave converter and at a temperature of at least 20°C.

A four-dial Wheatstone bridge with a digital null meter was constructed as a back-up for the digital ohm meter and as a portable field meter. This meter had a working accuracy of approximately $\pm 5 \Omega$ at 4,000 Ω . This meter was used primarily with the shallow temperature probe for measuring temperatures near the surface.

Calibration--

The thermistors used in this study are designed to be calibrated by Yellow Springs, and all thermistors of this type have the same calibration curve with a maximum error of 0.1°C. These probes are guaranteed to remain calibrated for 1 yr, which was approximately the length of the study period.

The thermistors purchased as a unit (those used in this study) were calibrated with respect to each other so that temperatures between probes could be compared with an accuracy of $\pm 0.05^{\circ}\text{C}$.

Investigators--

This experiment was conducted by Charles Andrews, who at the time of the experiment was working toward a Ph.D. degree in Geology at the University of Wisconsin-Madison. The experiment was conducted at the Columbia site under the supervision of Professor Mary Anderson. Field assistants helped in the collection of this data.

Supporting Documents

Same as data set C8B1.

DATA SET C8B3: TEMPERATURES IN THE VERTICAL PLANE EAST AND WEST OF THE COOLING LAKE OF THE COLUMBIA GENERATING STATION (1977-78)

Data Summary

Investigators--

C. Andrews and M. Anderson.

Abstract--

This data set contains weekly temperature ($^{\circ}\text{C}$) readings obtained at several depths in 11 wells during 1977 and 1978. Ground water temperatures were monitored in several vertical grids extending perpendicular to the east and west dikes at different distances from the generating station, which is located at the north end of the cooling lake.

Dates of Research--

April 1977-January 1978.

Data Form--

Computer file containing 261 units with one card-image/unit.

Data Format

Field Description--

<u>Column</u>	<u>Format</u>	<u>Description</u>
1-3	13	Well number
5-7	F3.0	Depth (m) of readings
9-10	12	Month

11-12	I2	Day
13-14	I2	Year
16-20	F5.2	Well temperature (°C)
22-23	I2	Month
24-22	I2	Day
26-27	I2	Year
29-33	F5.2	Well temperature (°C)
35-36	I2	Month
37-38	I2	Day
39-40	I2	Year
42-26	F5.2	Well temperature (°C)
48-49	I2	Month
50-51	I2	Day
52-53	I2	Year
55-59	F5.2	Well temperature (°C)
61-62	I2	Month
63-64	I2	Day
65-66	I2	Year
68-72	F5.2	Well temperature (°C)

Missing Data--

Missing data are indicated by 999. Unused data fields contain 888888 for month, day, and year.

Data Sample

The sample presented here is 10 records, 1 to 10, of the 261 records included in data set C8B3.

1234567890123456789012345678901234567890123456789012345678901234567890

24	2.	42277	13.79	53177	999	51677	14.29	60377	999	60777	999
24	2.	61477	999	61977	999	62377	999	70577	999	71177	999
24	2.	71477	999	71877	999	72177	999	72577	999	72977	999
24	2.	80377	999	81077	999	81377	999	90377	999	91877	999
24	2.	100177	999	101677	999	112077	999	888888	999	888888	999
24	3.	42277	9.09	53177	14.23	51677	12.58	60377	14.45	60777	14.72
24	3.	61477	17.98	61977	19.43	62377	19.78	70577	23.99	71177	999
24	3.	71477	999	71877	24.69	72177	25.71	72577	999	72977	999
24	3.	80377	999	81077	27.97	81377	999	90377	999	91877	25.01
24	3.	100177	26.26	101677	21.53	112077	999	888888	999	888888	999

Quality Assurance

Objectives--

The objectives for this data set are similar to the objectives for the preceding data set. This data set differs in that it presents temperature readings for more than one vertical cross section.

Monitoring Sites and Depths--

Wells 43, 140, and 143 are situated along an east-west line perpendicular to the cooling lake dike, between the cooling lake and the Wisconsin River (Figure 14). Wells 35, 36, 37, and 68 are situated in a similar east-west line, perpendicular to the cooling lake dike further north. Wells 74 and 75 are situated together along an east-west line perpendicular to the drainage ditch east of the cooling lake. Wells 24 and 28 are situated at separate points near the west dike of the cooling lake. Table 25 lists the distances from the sampling points to the dike and the depths at which measurements were obtained.

Monitoring Procedure--

Temperature measurements for this data were obtained from 11 wells which were 3.175 cm in diameter and were constructed of either galvanized pipe or PVC pipe.

Temperature readings were obtained with several Yellow Springs Instrument Company Series 400 thermistors which were used as sensors lowered into the wells. These thermistors were purchased as units designed for this purpose; they were sealed by the manufacturer in an epoxy resin and were attached to shielded cables. The maximum diameter of each assembly was 0.4 cm. The time constant of these thermistors is 7 sec.

Analytical Procedure--

Same as data set C8B2.

Critical Temperature Gradient--

Same as data set C8B2.

Equipment--

Same as data set C8B2.

Calibration--

Same as data set C8B2.

Investigators--

Same as data set C8B2.

Supporting Documents

Same as data set C8B1.

TABLE 25. TEMPERATURE SAMPLING POINTS: LOCATIONS, DEPTHS,
PROBES, AND FREQUENCIES OF READINGS

Sampling point number	Distance from dike (m)	Depth below surface at which temperature was measured (m)	Probe used to take temperature
130	2	0.15, 0.91, 1.52, 3.05, 6.10, 8.70	In situ probe
131	15	0.15, 0.46, 0.91, 1.51, 3.05, 4.57, 6.10, 9.76	In situ probe
132	32.5	0.15, 0.46, 0.91, 1.52, 3.05, 4.57, 6.10, 9.76	In situ probe
133	51		In situ probe
134	86		In situ probe
135	131.5		In situ probe
35	3	2, 3, 4, 5, 6, 7, 8, 9	probe lowered down 3.175 cm; PVC pipe
36	31	2, 4, 6, 7, 8	probe lowered down 3.175 cm; PVC pipe
37	61	2, 3, 4, 5	probe lowered down 3.175 cm; PVC pipe
68	194	4, 6, 8, 10, 12	probe lowered down 3.175 cm; galvanized pipe
24	2	3, 4, 5, 6, 7, 8, 9, 10	probe lowered down 3.175 cm; PVC pipe
28	2	2, 4, 6, 8, 10, 12, 13	probe lowered down 3.175 cm; PVC pipe
140	3	2, 4, 6, 8	probe lowered down 3.175 cm; galvanized pipe

(continued)

Table 25 (continued)

Sampling point number	Distance from dike (m)	Depth below surface at which temperature was measured (m)	Probe used to take temperature
143	37	2, 4, 6, 8	probe lowered down 3.175 cm; galvanized pipe
43	126	2, 4, 6, 8, 10	probe lowered down 3.175 cm; galvanized pipe
73	west side of ditch	1, 2, 3, 4, 5, 6, 7, 8, 9	probe lowered down 2.54 cm; PVC pipe
74	east side of ditch	1, 2, 3, 4	probe lowered down 3.175 cm; PVC pipe
75	14 m east of ditch	4, 6, 8, 10, 12, 16, 18, 20, 21	probe lowered down 3.175 cm; galvanized pipe
1		10, 12, 14, 16, 18, 20	probe lowered down 3.175 cm; galvanized pipe
57		8, 10, 12, 14	probe lowered down 3.175 cm; galvanized pipe
L1/L2	Lake inlet and outlet		thermistors
Areal coverage of marsh		0.1, 0.9 m at 45 locations in marsh	in situ
Transect 1 to transect 52	0.2 m	1.0, 3.0 m	shallow temperature probe

DATA SET C8B4: TEMPERATURES AT TWO LEVELS OF THE HORIZONTAL PLANE AT 40
MONITORING STATIONS AT THE COLUMBIA GENERATING STATION (1977-78)

Data Summary

Investigators--

C. Andrews and M. Anderson.

Abstract--

This data set contains the results of a study that monitored differences in the movement of heat away from the cooling lake through the ground water at different points along the west dike. Temperature readings were obtained at two shallow depths, 0.5 and 1.5 m, at the stake nearest the dike in each of the first 40 vegetation transects established by the Wetland Plants subproject (data set C14A1). During the 2 yr of the study, measurements were taken at 0.5 m on five dates and at 1.5 m on four dates.

Dates of Research--

30 September 1977, 23 October 1977, 3 December 1977, 10 January 1978, and 31 March 1978.

Data Form--

Computer file containing 9 units with nine card-images/unit.

Data Format

<u>Column</u>	<u>Format</u>	<u>Description</u>
<u>Title Card</u>		
10	I1	Transect number
12-17	I6	Date

Data Cards (eight cards per monitoring date)

1-2	I2	Site
5-9	F5.2	Temperature (°C)
12-1	I2	Site
16-20	F5.2	Temperature (°C)
23-24	I2	Site
27-31	F5.2	Temperature (°C)
34-35	I2	Site
38-42	F5.2	Temperature (°C)
45-46	I2	Site
49-53	F5.2	Temperature (°C)

Missing Data--

Missing data are indicated by 999.

Data Sample

The sample presented here is 2 records, 1 to 2 of the 9 records included in the complete data set C8B4.

1234567890123456789012345678901234567890123456789012345678901234567890

1 011078																																							
1	999	2	11.79	3	14.19	4	17.16	5	15.10																														
6	14.54	7	15.53	8	14.56	9	15.53	10	14.62																														
11	15.34	12	16.27	13	11.39	14	9.00	15	10.84																														
16	9.94	17	16.67	18	11.05	19	10.12	20	20.63																														
21	999	22	18.63	23	9.48	24	12.42	25	13.34																														
26	14.67	27	12.71	28	12.72	29	10.74	30	12.15																														
31	17.54	32	14.33	33	17.96	34	9.34	35	12.82																														
36	13.20	37	12.20	38	999	39	999	40	999																														
2 093077																																							
1	999	2	17.50	3	999	4	21.50	5	999																														
6	27.00	7	26.50	8	999	9	26.00	10	21.00																														
11	20.00	12	18.00	13	22.00	14	22.50	15	24.50																														
16	23.00	17	23.00	18	27.00	19	27.00	20	17.24																														
21	15.25	22	15.25	23	27.25	24	27.00	25	28.50																														
26	17.25	27	16.50	28	15.50	29	15.00	30	17.00																														
31	999	32	20.00	33	20.50	34	20.00	35	28.00																														
36	27.75	37	27.00	38	23.00	39	27.00	40	22.00																														

Quality Assurance

Objectives--

The objectives are similar to the objectives for the three preceding data sets: to provide a basis for simulating the response of ground water temperatures to seasonal changes in cooling lake temperatures. This data set also provides information concerning variations in temperature response at different points along the west dike caused by variations in the composition of the subsurface and in temperature patterns in the cooling lake itself.

Monitoring Sites and Depths--

Temperature readings were obtained at 0.5 and 1.5 m at the stake nearest the dike in each of the first 40 transects established by the Wetland Plants subproject (see Section 14) west of the cooling lake. These sites were 0 to 2 m from the edge of the dike.

Monitoring Procedure--

Yellow Springs Instrument Company Series 400 thermistors mounted in brass rods (diameter 0.95 cm, length 2.1 m) were pushed into position by hand to obtain temperature readings. These thermistors were purchased as units designed for this purpose; each unit was sealed by the manufacturer in

an epoxy resin and was attached to a shielded cable. The maximum diameter of the assembly was 0.4 cm.

Analytical Procedure--

Same as data set C8B2.

Critical Temperature Gradient--

Same as data set C8B2.

Equipment--

Same as data set C8B2.

Calibration--

Same as data set C8B2.

Investigators--

Same as data set C8B2.

Supporting Documents

Same as data set C8B1.

DATA SET C8C1: QUALITY OF THE GROUND WATER IN THE VICINITY OF THE COLUMBIA GENERATING STATION 1972-77

Data Summary

Investigators--

G. Gibbs, N. Jacquet, C. Andrews, D. Stephenson, and M. Anderson.

Abstract--

This data set contains the results of a survey from 1 June 1972 to 19 July 1977 that monitored the impact of the Columbia Generating Station on the quality of the ground water in the surrounding area. Samples were collected from 53 sampling stations and analyzed for the amount of dissolved K, Na, Ca, Mg, Cl, PO_4 -P, SO_4 -S, NH_4 -N, NO_3 -N, and organic N. In addition, pH and conductivity were measured.

Dates of Research--

1 June 1972-19 July 1977.

Data Form--

Computer file containing 199 units with one card-image/unit.

Data Format

Field Description--

<u>Column</u>	<u>Format</u>	<u>Description</u>
1-2	I2	Month
3-4	I2	Day
5-6	I2	Year
8-10	I3	Well number
12-15	F4.2	pH
17-21	F5.2	Conductivity (mhos $\times 10^{-15}$ /cm)
23-27	F5.2	K concentration (ppm)
29-33	F5.2	Na concentration (ppm)
35-39	F5.2	Ca concentration (ppm)
41-45	F5.2	Mg concentration (ppm)
47-51	F5.2	Cl concentration (ppm)
53-57	F5.2	PO ₄ -P concentration (ppm)
59-63	F5.2	SO ₄ -S concentration (ppm)
65-69	F5.2	NH ₄ -N concentration (ppm)
71-75	F5.2	NO ₃ -N concentration (ppm)
77-80	F4.2	Organic N concentration (ppm)

Missing Data--

Missing data are indicated by 999.

Data Sample

The sample presented here is 14 records, 1 to 14, of the 199 card images included in the complete data set C8C1.

1234567890123456789012345678901234567890123456789012345678901234567890
062877 1 999 999 14.50 4.40 9.90 7.90 6.50 999 5.50 999 999 999
092375 1 999 28.00 2.00 6.20 8.50 20.00 26.80 -.01 10.30 .40 -.10 999
051175 1 8.00 27.00 1.00 9.50 10.00 21.00 24.20 -.02 16.60 .60 .02 .82
031175 1 9.00 30.00 2.50 7.00 10.00 15.00 31.50 -.02 17.40 .66 -.01 2.02
160573 1 8.40 29.00 1.90 8.70 22.00 18.20 25.50 -.02 18.60 .75 .13 .57
080573 1 7.10 29.00 2.30 9.20 18.00 15.20 27.40 -.02 21.60 .80 .07 .76
071977 2 999 999 10.50 3.00 9.50 10.00 5.00 999 4.00 999 999 999
092375 2 999 28.00 1.80 3.50 11.90 25.20 8.20 -.01 1.70 -.10 .20 999
051175 2 7.50 35.00 2.00 7.80 26.00 18.00 9.50 -.02 2.90 .40 -.01 .52
031175 2 8.60 35.00 2.50 6.00 28.00 13.00 10.80 -.02 28.80 .42 -.01 .56
100673 2 8.60 50.00 1.50 6.40 43.80 30.00 7.40 -.02 15.00 .30 .13 .24
080573 2 7.40 28.00 2.60 8.10 29.00 12.70 11.40 -.02 20.00 .24 -.01 .46
060172 2 8.30 52.50 4.20 4.00 26.00 23.00 16.00 -.02 16.60 -.01 -.01 .43
071977 3 999 999 1.00 7.00 18.00 16.00 6.50 999 11.20 999 999 999

Quality Assurance

Objectives--

The purpose of this study was to identify patterns in the chemical composition of the ground water in the vicinity of the Columbia Generating Station before (1 June 1972 to 13 June 1974) and after (14 June 1974 to 19 July 1977) the filling of the cooling lake and ashpit. This study provides an adequate basis of knowledge with which to simulate the hydrologic regime. After the initial sampling to identify patterns, less intensive monitoring was continued to provide a check on predictions and a check for changing conditions. Beyond this, chemical sampling of waters was left to the Aquatic Chemistry Subproject.

Sampling Sites--

Based on a study of ground water circulation patterns around the generating station, 53 sampling stations were selected (Figure 14). The stations were chosen to represent the flow patterns of the water quality parameters monitored.

Sample Collection--

The sampling stations were 1.25 inch well-point piezometer wells, which were driven into place in the lowlands and augered into place in the uplands. Each well was positioned so that it was open to the aquifer just below the water table.

Sampling was conducted on an irregular basis since this study initially identified patterns in the chemical composition and continued as a check on modeling predictions for the model that was developed to simulate the impact of the cooling lake on ground water temperature and water quality. The length of the interval between samples was determined by the rate of change observed in other parameters under study.

The water samples were taken from the wells with a copper bailer. Starting in January 1975, a quantity of water equal to at least twice the volume of water in the well was removed preceding sampling. Before a sample was taken from the wells in the wetland or wells in which water levels were within 5 m of the surface, the wells were pumped with a hand-operated vacuum pump until the conductivity stabilized. Conductivity was recorded on a Yellow Springs Instrument Model 33 S-C-T meter. The samples were stored in sterilized plastic bottles, cooled in an ice chest in the field, and maintained at a temperature of 1 to 3°C. The samples were brought back to the laboratory and analyzed within 2 weeks.

Analytical Procedures--

The water samples were analyzed by J. Jenson and J. Parsen, Soils Specialists at the Soils and Plant Laboratory, Univ. of Wisconsin-Extension, Madison, WI. The samples were filtered through a 0.45-mm filter prior to analysis for all analyses except organic N.

Conductivity--An Industrial Instruments Model RD-15 Solu Bridge was used for conductivity measurements. The conductivity cell of the bridge was filled with a sample, the temperature control was set at room temperature, and the bridge was balanced. The conductivity was read in mhos $\times 10^{-15}/\text{cm}$. The conductivity reading was multiplied by the cell constant. The cell constant (K) was determined by measuring the conductivity of 0.01N KCl and by calculating the constant with the equation:

$$K = \frac{\text{conductivity of 0.01N KCl}}{\text{measured conductivity of 0.01N KCl}} = \frac{141.2 \times 10^{-15} \text{ mhos/cm}}{\text{measured conductivity}}$$

pH--A Coleman Companion Model 31 glass electrode pH meter was used for pH measurements. The electrode was calibrated with buffer solutions of pH 4.0 and 7.0 before each day's set of samples was run. In addition, the pH of a sample with known pH was tested since pH values of 4.0 and 7.0 were relatively acid compared to samples. At the start of each day's operation, the reference electrode was adjusted to achieve a good liquid junction between the KCl solution within the electrode and the sample solution.

Dissolved Reactive Phosphorus ($\text{PO}_4\text{-P}$) Analysis--A Bausch and Lomb Spectronic 88 spectrometer was used for P measurement. The analysis was carried out according to the Murphy-Reilly procedure, a spectrophotometric technique based on the colorimetric determination of a red phosphomolybdenum complex after digestion with H_2SO_4 and $(\text{NH}_4)_2\text{S}_2\text{O}_8$. The dissolved reactive P was analyzed with the above procedure without digestion but with filtration. The relative error is percent phosphorus $\times 2.38$.

$\text{NH}_4\text{-N}$, $\text{NO}_3\text{-N}$ and Organic N Analyses--The $\text{NH}_4\text{-N}$ was separated by steam distillation, collected in boric acid, and determined by titration with standard acid. Magnesium oxide was used for distillation of $\text{NH}_4\text{-N}$ and finely divided Devarda alloy was used for reduction of NO_3 and organic N to NH_4 . The analyses were carried out according to the Bremner-Keeney procedure (1965). An apparatus assembled in the laboratory was used for N measurements, based on the Bremner-Keeney specifications. The accuracy of these measurements was $< 0.2\%$.

$\text{SO}_4\text{-S}$ Analysis--A Coleman Model 9 Nepho-Colorimeter was used for SO_4 measurements. The measurements were made by determining the concentration of a BaSO_4 suspension. The nepho-colorimeter was calibrated with SO_4 standards which were weighed on a Mettler H33AR scale. This instrument had a ± 0.1 mg deviation.

Calibration--For all of the above analyses (except flame atomic absorption), calibration was accomplished using standards before each analysis. The standards were prepared with reagent chemicals.

Reproducibility--The reproducibility of water samples was checked by taking more than one sample from a well on a given day, by collecting samples from a well at 2-day intervals for 1 week, and by taking samples

from a well after varying amounts of pumping. Twenty-two samples were checked for reproducibility. These checks showed that, except for K and SO_4 concentrations, the values are reproducible to within $\pm 20\%$. The K and SO_4 concentrations varied as much as 100% between samplers from the same well for samples taken only 2 days apart. The amount of pumping before sampling was not found to be an important variable in determining the chemical quality of the sample if the minimum procedure outlined in the methodology section was followed. The extreme of no pumping produced very erratic results.

Investigators--

This study was conducted successively by three investigators. G. Gibbs was the investigator until 1 March 1973. At the time of the experiment, he was working toward an M.S. degree in Geology at the University of Wisconsin-Madison under the supervision of Professor D. Stephenson. From 2 March 1973 to Nov. 1974, the investigator was N. Jacquet, who at the time of the experiment was taking graduate courses at the University of Wisconsin-Madison. His work at the Columbia site was supervised by Prof. D. Stephenson. The experiment was concluded after Nov. 1974 by Charles B. Andrews, who at the time of the experiment was working toward a Ph.D. degree in Geology at the University of Wisconsin-Madison. His work was supervised by Professor Mary Anderson. The above mentioned individuals carried out the data collection aspect of the study with the help of field assistants. The chemical analyses were conducted in the Soils and Plant Laboratory, University Wisconsin-Extension, Madison, WI, by J. J. Genson and J. Parsen, both Soil Specialists.

Supporting Documents

Andrews, Charles B. 1976. An analysis of the impact of a coal-fired power plant on the groundwater supply of a wetland in central Wisconsin. M.S. Thesis. University of Wisconsin-Madison. 83 p.

Andrews, C., and M.P. Anderson. 1980. Impacts of coal-fired power plants on local ground-water systems. EPA-600/3-80-079. U.S. Environmental Protection Agency, Cincinnati, Ohio. 203 p.

Gibbs, Gregg. 1973. The hydrogeology of the Columbia Electric Generating Station site. M.S. Thesis. University of Wisconsin-Madison. 30 p.

Hydrogeology. In: Documentation of environmental change related to the Columbia Electric Generating Station. Institute for Environmental Studies, Reports 46, 58, 62, 66, 69, 82. University of Wisconsin-Madison.

AUXILIARY DATA SET C8D1: CONSTRUCTION, LOCATION, AND DIMENSIONS OF THE
HYDROGEOLOGY SAMPLING POINTS

Data Summary

Investigators--

G. Gibbs, N. Jacquet, and D. Stephenson.

Abstract--

This data set contains background information for all the preceding data sets concerning the observation wells (see Figure 14) that were installed near the Columbia Generating Station to monitor the impact of the cooling lake on the ground water system. These records included the date of installation, elevation, depth, length of pipe, and distance from the dike.

Dates of Research--

1971-1975.

Data Form--

Computer file containing 104 units with one card-image/unit.

Data Format

Field Description--

<u>Column</u>	<u>Format</u>	<u>Description</u>
1-3	I3	Well number
5	I1	Description; 1=upland well, 2=shallow well in wetland, 3=deep well in wetland, 4=marsh well in wetland, 5=ashpit, 6=lake, 7=drainage ditch, 9=not given
7-12	F6.3	Elevation (ft above MSL)
14-17	F4.1	Pipe length (ft)
19-22	F4.1	Approximate average depth (ft)
24-26	I3	Approximate distance from dike (ft)
28-29	I2	Month installed
30-31	I2	Year installed
33-34	I2	Month removed (99 means not removed)
35-36	I2	Year removed (99 means not removed)

Missing Data--

Missing data are indicated by blank spaces and 999.

Data Sample

The sample presented here is 15 units, 1 to 15, of the 104 auxiliary data set C8D1.

1234567890123456789012345678901234567890

1	1	818.76	80.5	999	631	1171	9999
2	1	818.08	51.0	999	631	1171	9999
3	1	791.02	24.0	999	999	0672	1073
4	1	790.65	16.0	999	999	0672	1073
5	9						
6	2	784.59	10.5	999	200	0772	1075
7	4						
8	2	784.51	999	999	0	0574	1075
9	2	784.53	10.5	6.1	200	0772	9999
10	4						
11	2	783.67	12.5	8.8	200	0672	1075
12	4						
13	9	785.63	999	5.2	999	0574	0878
14	4						
15	2	784.01	999	6.0	160	0672	9999

Supporting Documents

Same as data set C8A1.

REFERENCES

- American Public Health Association, American Water Works Association, Water Pollution Control Federation. 1975. Standard methods for the examination of water and wastewater. Washington, D.C. 890 p.
- Bremner, J.M., and D.R. Keeney. 1965. Steam distillation methods for determination of ammonium, nitrate and nitrite. Anal. Chem. Acta 32:485-495.
- Liegel, E.A., and E.E. Schulte (eds.) 1970, revised 1977. Wisconsin soil testing plant analysis and feed and forage analysis procedures. No. 6 Soil Fertility Series. Department of Soil Science, College of Agricultural and Life Sciences, University of Wisconsin-Madison. 48 p.
- Sammel, E.A. 1958. Convective flow and its effect on temperature lagging in small diameter wells. Geophysics 33:1004-1012.

SECTION 9

PLANT DAMAGE

The main goal of the plant damage subproject was to document changes in the incidence of air pollution injuries to terrestrial vegetation before and after the initiation of operations at the Columbia Generating Station.

Specific objectives were (1) to determine the impact of the generating station on several plant species known to be sensitive bioindicators of the presence of pollutants and (2) to document the concentrations of air pollutants present in the ambient air.

In relation to objective (1) three plant species were studied. For the first species, alfalfa, two studies were conducted. The first study is a 7-yr survey of field sampling and is documented in data sets C9A11 and C9A12. Data set C9A11 (Alfalfa sampling near the Columbia Generating Station (1972-77)) documents the results of a survey which sampled 16 alfalfa sites around the station. Data set C9A12 presents Sites maps for the alfalfa field study. The second study, which evaluated the impact of pollutants on alfalfa with open top chambers, is documented in data set C9A2 (Alfalfa sampling and environment measurements in open-top field chambers (1976)).

The second species studied by the plant damage subproject is lichens. The data are presented in data sets C9A31 and C9A32. Data set C9A31 (Lichen sampling in the vicinity of the Columbia Generating Station) presents the results of a survey of corticolus lichen communities conducted before and after the operation of the power plant. Data set C9A32 (Tree sampling in the lichen study (1974)) documents the tree communities in each of the lichen sites.

The third plant species studied by the plant damage subproject is Eastern white pine. The data for this species are presented in data set C9A41 and C9A42. Data set C9A41 (Tipburn injuries to eastern white pines near the Columbia Generating Station (1971-1978)) documents the results of an 8-yr survey which assessed the changes of tipburn injuries at 15 sites. The sites maps are documented in data set C9A42 (Sites maps for the white pine study).

In relation to objective (2), three pollutants were monitored; O_3 , N, and oxidants. The data are presented in data sets C9B1, C9B2, and C9B3. Additional air pollution data are presented in Section 17 (Wisconsin Power

and Light Company). Data set C9B1 (Ozone monitoring at the Messer site near the Columbia Generating Station (1976-78)) includes hourly-average records of O₃ levels. Data set C9B2 (Nitrogen oxides monitored near the Columbia Generating Station (1976-78)) includes hourly averages of NO, NO₂, and NO_x. Data set C9B3 (Oxidants monitored near the Columbia Generating Station (1973-77)) includes hourly-average readings of oxidants.

The investigators for this subproject were Theodore W. Tibbitts, Professor, Department of Horticulture; David Olszyk, Susan Will-Wolf, David Karnovsky, and Janice Kobriger, who at the time of the studies were working toward Ph.D. degrees in Horticulture; and Harold Frank, the group technician; all at the University of Wisconsin-Madison. This report was compiled by Saya Shacham, Data Center Analyst, Water Resources Center.

DATA SET C9A11: ALFALFA SAMPLING IN THE VICINITY OF THE COLUMBIA GENERATING STATION (1972-77)

Data Summary

Investigators--

D. M. Olszyk and T. W. Tibbitts.

Abstract--

A 7-yr survey was conducted to evaluate the changes in air pollution injury to alfalfa in relation to operation of the Columbia Generating Station. Data were collected from 16 alfalfa sites at approximately 3, 5, 8, and 16 km west, northeast, southeast, and southwest of the Columbia Generating Station. Data were collected at the time of the three alfalfa harvests (June-Sept.). For the first two harvests, estimates for the amount of chlorosis and necrosis and the dry weight of the alfalfa were obtained. For the third harvest, only a visual estimate of injury was made. The stage of alfalfa flowering also was recorded for each harvest in each field.

Dates of Research--

1972-1977.

Data Form--

Computer file containing 112 units with three card-images/unit.

Data Format

Field Description--

Each unit in the file contains three card images. The first 2 card images are identical.

Cards #1 and #2 (First and second harvests)

<u>Column</u>	<u>Format</u>	<u>Description</u>
1-2	I2	Year
4	I1	Harvest; 1=1st harvest; 2=2nd harvest
6-7	I2	Date harvest began
9	I1	Month
11-12	I2	Site
14-16	I3	Percentage of leaves damaged by chlorosis (lower third)
18-20	I3	Percentage of leaves damaged by chlorosis (middle third)
22-24	I3	Percentage of leaves damaged by chlorosis (upper third)
26-28	I3	Percentage of leaves damaged by chlorosis (lower third)
30-32	I3	Percentage of leaves damaged by chlorosis (middle third)
34-36	I3	Percentage of leaves damaged by chlorosis (upper third)
38-40	I3	Dry weight of sample (g/m ²)
42	I1	Bloom condition of the field; 0=no bud; 1=bud; 2=early bloom; 3=bloom; 4=harvested; 9=no data

Card #3 (Third harvest)

<u>Column</u>	<u>Format</u>	<u>Description</u>
1-2	I2	Year
4	I1	Harvest; 3=3rd harvest
6-7	I2	Date
9	I2	Month
11-12	I2	Site
22-24	I3	Percentage of leaves damaged by chlorosis (whole plant)
34-36	I3	Percentage of leaves damaged by chlorosis (whole plant)
38-40	I3	Bloom condition of the field (same as on card #1)

Missing Data--

Missing data are indicated by 999.

Data Sample

The sample presented here is 3 units, 38-40, out of 112 units included in data set C9A11.

123456789012345678901234567890123456789012

74	1	1	6	06	51	17	03	04	03	01	258	9
74	2	29	7	06	45	44	31	08	07	03	071	3
74	3	23	9	06			25			25	999	9
74	1	1	6	07	55	19	01	06	02	00	301	9
74	2	29	7	07	28	26	04	25	10	02	231	3
74	3	23	9	07			00			00	999	9
74	1	1	6	08	32	17	01	06	03	00	344	9
74	2	29	7	08	38	33	39	18	13	13	124	0
74	3	23	9	08			12			25	999	9

Quality Assurance

Objectives--

The purpose was to document the type and amount of field damage to herbaceous crops before and after the initiation of operation at the Columbia Generating Station, and alfalfa (*Medicago sativa* L.) was the major crop monitored because it is sensitive to SO₂, and its symptoms are quite distinctive for SO₂ pollution.

Another reason for monitoring alfalfa is because it is widely distributed near the station and is a valuable crop for dairy farming which is prevalent in the region.

Sampling Sites--

A permanent network of monitoring sites was established in 1971 with sites located at approximately 3, 5, 8, and 16 km from the generating station in each of four directions: southwest, west, northeast and southeast (Figure 15). Each site was located within an existing, vigorous alfalfa field. All fields were privately owned, and permission was obtained to sample each site for as long as the monitoring program would continue. Sampling was begun in the spring of 1972. In subsequent years, if the field was planted in another crop or the alfalfa stand became poor, a new field was chosen within 0.5 km of the one previously sampled. Bar graphs in Table 27 indicate the number of years an individual sampling location was used and when locations were changed. Detailed maps of all sampling locations are documented in data set C9A12.

Sampling Methods--

In each field a center point was selected approximately 18 m (60 ft) from the nearest road or field boundary. From this center point, subsampling plots were marked off at distances of 9 m (30 ft) north, south, east, and west of the sampling point. For each plot a 0.2 m² area was marked off. Alfalfa plants within this area were examined and scored for the percentage of chlorosis (yellowing) and necrosis (dead areas) present on the leaves. The percentage of leaves showing injury was estimated. These

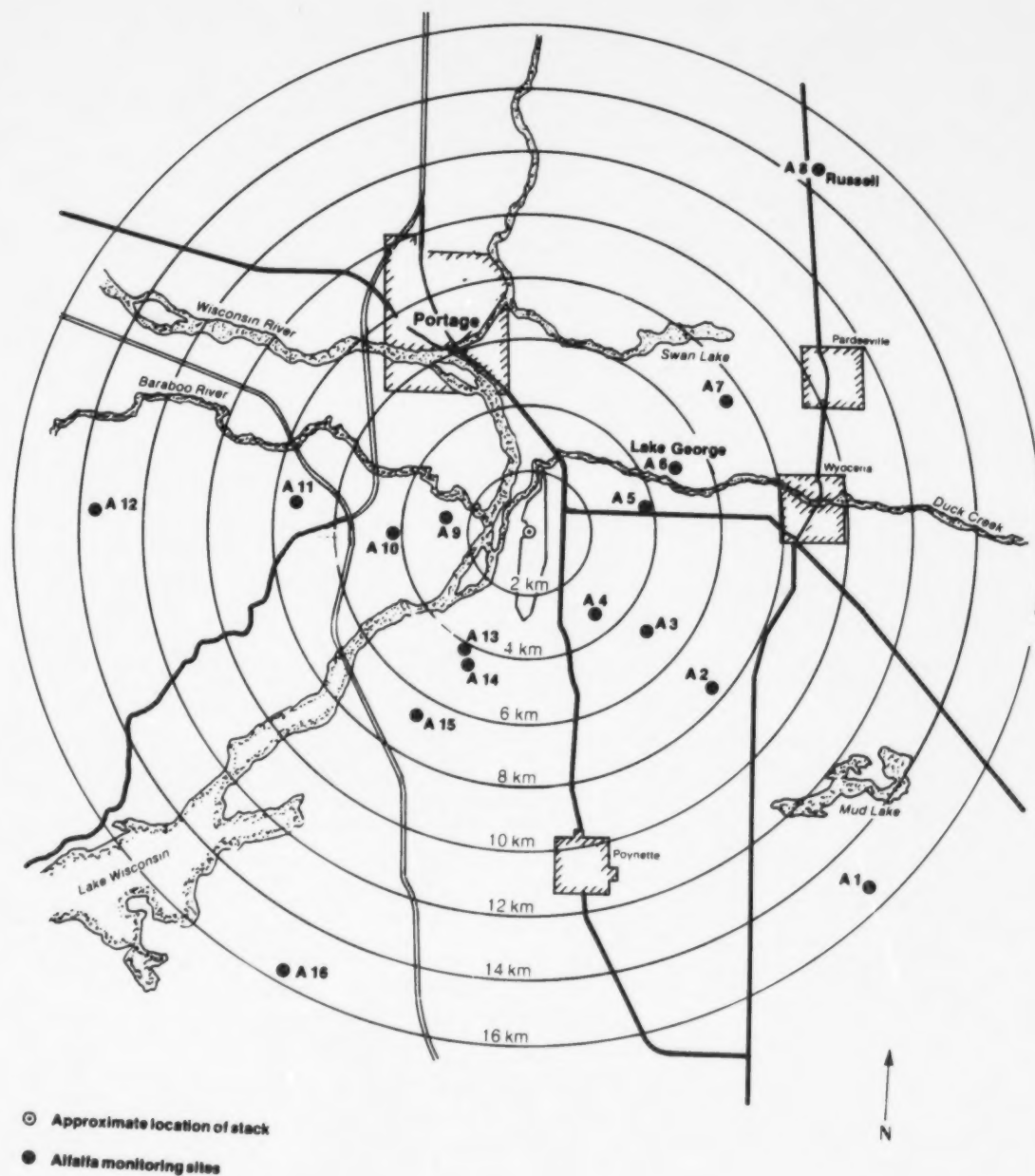


Figure 15. Location of alfalfa sampling sites around the Columbia Generating Station.

figures were multiplied to obtain the percentage of total leaf area affected. Injury was recorded separately for each of three parts of the alfalfa plant: the lower 1/3, the middle 1/3, and the upper 1/3.

Possible causes of the leaf chlorosis and necrosis were evaluated in the field. Symptoms were compared with those pictorially documented in Rohweder et al. (1972) including common fungal, bacterial, and viral diseases; nutrient deficiencies; insect infestations, and environmental stresses such as water stress, freezing, and sunscald. If the cause of the injury symptoms was questionable, samples of injured alfalfa leaves were placed in plastic bags and brought to Madison for laboratory examination. Photographs of alfalfa-injury symptoms were made for whole plants in the field and individual leaves after returning to the laboratory to document the injury symptoms that were observed.

Alfalfa Yield--

Measurement of alfalfa yield was made by harvesting all plants in the 0.2 m² area of each of the four plots in each field. Fresh weights of the samples were taken immediately and dry weights were taken after samples had been dried for 1 week at 40°C. The dry weights for alfalfa from each of the four plots were averaged to obtain a dry weight for each site.

Sites were sampled three times each summer a few days before the normal harvesting times for farms in the area. The first samples were taken in late May or early June, the second in late July or early Aug., and the third in late Sept. Sampling procedures for the first and second visits were as described above. At the third visit, field samples were not taken because of the wide variation in harvesting times, but photographs were taken and written records made of the types of plant injury present on individual plants in each field.

Sulfur Content--

During 1973 and 1978, the dried alfalfa samples from the June harvests were saved for S analysis. Samples were separated to provide only leaves of the alfalfa plants for analysis. Leaves were ground and analyzed by x-ray fluorescence to obtain a measurement of S in the tissue (Jenkins and Deuries 1973). The data are presented in Table 27.

Soil Samples--

Soil samples were obtained from each sampling site during 1978 in order to determine soil type. At each site a soil sample was taken from the field that was sampled for alfalfa during 1978. The fields were usually considered to be representative of the soil types for neighboring fields that were sampled in preceeding years. In cases where a field used in preceeding years was more than 100 m distance or had slightly different topography, a sample of soil also was taken. Samples were taken from the top 15 cm of the soil and were sent to the State Soil Testing Laboratory at Marshfield, WI, for analysis. The soil types ranged from sandy to loam in the different fields (Table 26).

TABLE 26. THE NUMBER OF YEARS ALFALFA SITES WERE SAMPLED AND THE TYPE OF SOIL AT EACH SITE

Site No.	Year Sampled						
	1972	1973	1974	1975	1976	1977	1978
1	LOAM			SANDY LOAM			
2	SANDY LOAM			LOAM			
3	SAND						SANDY LOAM
4	SANDY LOAM						
5	LOAMY SAND				SANDY LOAM		
6	SAND			LOAMY SAND			
7	SANDY LOAM						
8	LOAM						
9	LOAMY SAND						
10	SILT LOAM						
11	SILT LOAM						
12	SILT LOAM						
13	SANDY LOAM						
14	SAND			SANDY LOAM			
15	SANDY LOAM			LOAMY SAND			
16	LOAMY SAND						

TABLE 27. PERCENTAGE OF S IN ALFALFA LEAVES
FROM JUNE HARVESTS IN 1973 AND 1978^a

Site	1973	1978
1	0.45	0.40
2	-	0.46
3	2.30	-
4	-	0.34
5	0.31	0.38
6	0.26	0.36
7	0.33	0.43
8	0.33	0.44
9	0.32	0.41
10	0.48	0.45
11	0.36	0.45
12	0.37	0.44
13	0.31	0.44
14	0.38	0.40
15	0.36	0.40
16	0.32	0.41
Average	0.35 + 0.06	0.41 + 0.04

^aAverage of four samples taken at each site.

Supporting Documents

Plant damage. In: Documentation of the environmental change related to the Columbia Electric Generating Station. Institute for Environmental Studies, Reports 46, 58, 62, 69, 82, University of Wisconsin-Madison.

Tibbitts, T.W., S. Will-Wolf, D. Karnovsky, and D. Olszyk. (Unpublished report.) Impact of air pollution on vegetation near the Columbia Generating Station. U.S. Environmental Protection Agency, Cincinnati, Ohio.

DATA SET C9A12: SITE MAPS FOR THE ALFALFA FIELD STUDY

Data Summary

Investigators--

D.M. Olszyk and T.W. Tibbitts.

Abstracts--

This data set contains the maps of the alfalfa study sites (data set C9A11). Each of the 16 sites are documented in two maps. The first map

shows the exact location of the sampling sites on a township map. Another map shows each site in detail and indicates the relation of the sampling location to nearby trees, posts, and fence lines. On each map changes in field location within the site in successive years are documented.

Dates of Research--

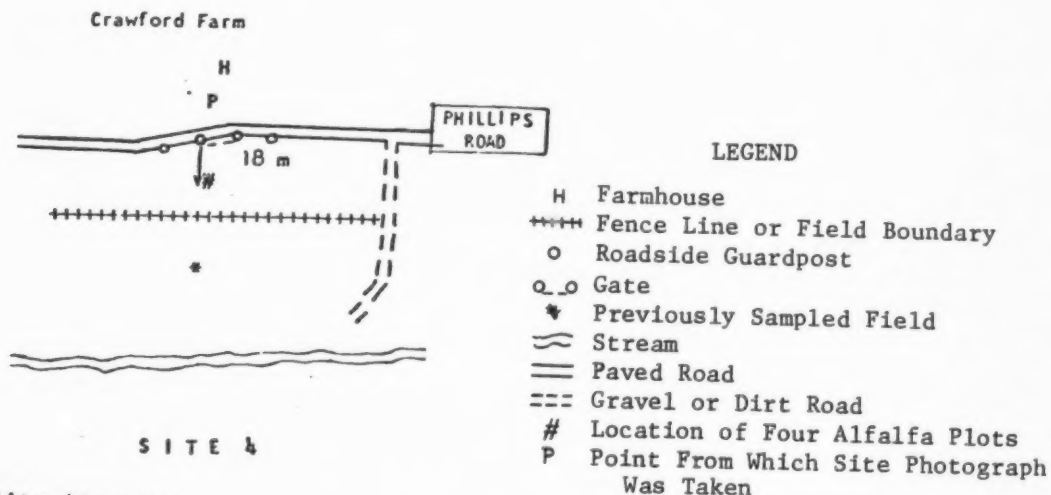
1973-1977.

Data Form--

This data set includes six township maps and 16 maps of the sites.

Data Sample

The following sample presents one of the 16 site maps included in data set C9A12. No sample is presented of the township maps which are also included in this data sheet.



Quality Assurance

Objectives--

The purpose for preparing these maps was to provide a record of the exact locations of the alfalfa sampling sites.

Sampling Sites--

Same as data set C9A11.

Preparatory Procedure--

The township maps documenting the locations of each site were copied from 1972 maps published by Rockford Map Publishing Company. The detailed site maps, which were hand drawn, show the exact location of each site. Each map depicts the relationship of sampling fields to trees, posts, and fence lines, but not according to scale. A new map was drawn whenever a field was changed.

Investigators--

Same as data set C9A11.

Supporting Documents

Same as data set C9A11.

DATA SET C9A2: ALFALFA SAMPLING AND ENVIRONMENT MEASUREMENTS FOR OPEN-TOP FIELD CHAMBERS (1976)

Data Summary

Investigators--

D.M. Olszyk, T.W. Tibbitts, and W.M. Hertzberg.

Abstract--

The impact of air pollutants on alfalfa in the vicinity of the Columbia Generating Station was evaluated with open-top field chambers during 1976. Six cylindrical open-top chambers were maintained at a site 8.3 km north of the station, three with charcoal filters and three without filters. The chamber plots were replicated with three open-area plots. Alfalfa yield and chlorotic injury were measured for each of the five quadrants assigned in each plot for each of three harvests. To compare the environment within the chambers and open-air plots, air flow, temperature, and evaporative water loss were measured.

Dates of Research--

April 1976-September 1976.

Data Form--

Computer file containing 63 units with seven card-images/unit.

Data Format

Field Description--

Card #1

<u>Column</u>	<u>Format</u>	<u>Description</u>
1	I1	Plot treatment; 1=chamber, filtered air; 2=ambient air, open area; 3=chamber, non-filtered air
2	I1	Chamber position-column (see Figure 16)
3	I1	Chamber position-Row (see Figure 16)
5-9	F5.1	June 4 alfalfa yield (g/m ²) for center area of: Quadrant 1=north
11-15	F5.1	Quadrant 2=east
17-21	F5.1	Quadrant 3=south
23-27	F5.1	Quadrant 4=west
29-33	F5.1	June alfalfa yield (g/m ²) for total area of: Quadrant 1=north
35-39	F5.1	Quadrant 2=east
41-45	F5.1	Quadrant 3=south
47-51	F5.1	Quadrant 4=west
80	I1	Image sequence, 1 for Card #1

Card #2

1	I1	Plot treatment (same as card #1)
2	I1	Chamber position: Column (see Figure 16)
3	I1	Chamber position - Row 1, 2, or 3 (see Figure 16)
5-9	F5.1	June 29 alfalfa yield for center area of: Quadrant 1=north
11-15	F5.1	Quadrant 2=east
17-21	F5.1	Quadrant 3=south
23-27	F5.1	Quadrant 4=west
29-33	F5.1	June 29 alfalfa yield (g/m ²) for total area of: Quadrant 1=north
35-39	F5.1	Quadrant 2=west
41-45	F5.1	Quadrant 3=south
47-51	F5.1	Quadrant 4=west
80	I1	Image sequence, 2 for Card #2

Card #3

1	I1	Plot treatment (same as card #1)
2	I1	Chamber position - Column (see Figure 16)
3	I1	Chamber position - Row (see Figure 16)
5-9	F5.1	September 2 alfalfa yield (g/m ²) for center area of: Quadrant 1=north
11-15	F5.1	Quadrant 2=east
17-21	F5.1	Quadrant 3=south
23-27	F5.1	Quadrant 4=west
		September 2 alfalfa yield (g/m ²) for total area of:

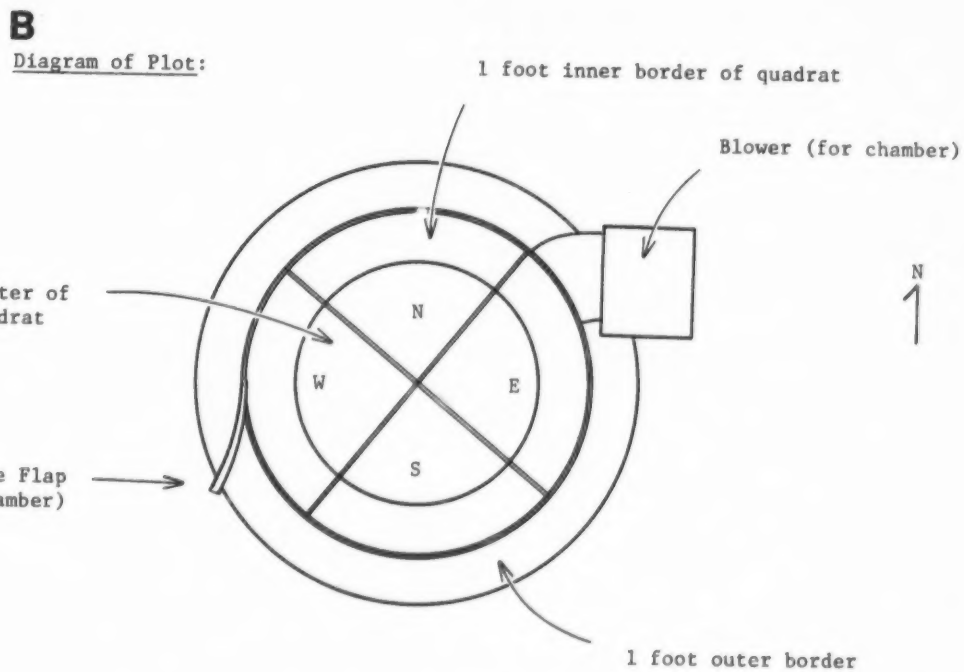
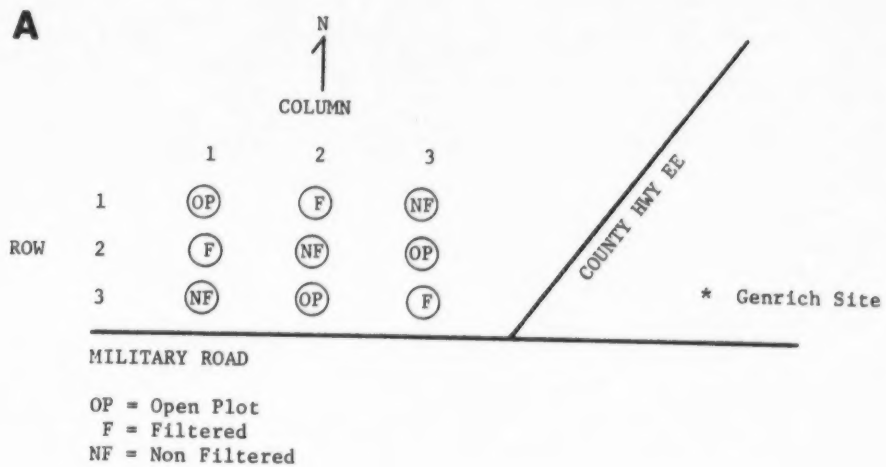


Figure 16. (A) The location of the open top chambers near the Genrich Site and (B) Diagram of the arrangement of one of the open top chambers.

29-33	F5.1	Quadrant 1=north
35-39	F5.1	Quadrant 2=east
41-45	F5.1	Quadrant 3=south
47-51	F5.1	Quadrant 4=west
80	I1	Image sequence, 3 for Card #3

Card #4

1	I1	Plot treatment (same as card #1)
2	I1	Chamber position - Column (see Figure 16)
3	I1	Chamber position - Row (see Figure 16)

Total season alfalfa yield (g/m^2) for center area

of:

5-9	F5.1	Quadrant 1=north
11-15	F5.1	Quadrant 2=east
17-21	F5.1	Quadrant 3=south
23-27	F5.1	Quadrant 4=west

Total season alfalfa yield (g/m^2) for total area of:

29-33	F5.1	Quadrant 1=north
35-39	F5.1	Quadrant 2=east
41-45	F5.1	Quadrant 3=south
47-51	F5.1	Quadrant 4=west
80	I1	Image sequence, 4 for Card #4

Card #5

1	I1	Plot treatment (same as card #1)
2	I1	Chamber position - Column (see Figure 16)
3	I1	Chamber position - Row (see Figure 16)

7:00 a.m. temperature ($^{\circ}\text{C}$) in:

5-9	F5.1	Quadrant 1=north
11-15	F5.1	Quadrant 2=east
17-21	F5.1	Quadrant 3=south
23-27	F5.1	Quadrant 4=west

7:00 a.m. temperature at center of plot

Noon temperature ($^{\circ}\text{C}$) in:

35-39	F5.1	Quadrant 1=north
41-45	F5.1	Quadrant 2=east
47-51	F5.1	Quadrant 3=south
53-57	F5.1	Quadrant 4=west

Noon temperature at center of plot

80 I1 Image sequence, 5 for Card #5

Card #6

1	I1	Plot treatment (same as card #1)
2	I1	Chamber position - Column (see Figure 16)
3	I1	Chamber position - Row 1, 2, or 3 (see Figure 16)

5:00 p.m. temperature ($^{\circ}\text{C}$) in:

5-9	F5.1	North quadrant
11-15	F5.1	East quadrant

17-21	F5.1	South quadrant
23-27	F5.1	West quadrant
29-33	F5.1	5:00 p.m. temperature ($^{\circ}\text{C}$) at center of plot
		7:00 p.m. temperature ($^{\circ}\text{C}$) in:
35-39	F5.1	Quadrant 1=north
41-45	F5.1	Quadrant 2=east
47-51	F5.1	Quadrant 3=south
53-63	F5.1	Quadrant 4=west
59-63	F5.1	7:00 p.m. temperature ($^{\circ}\text{C}$) at center of plot
80	I1	Image sequence, 6 for Card #6

Card #7

1	I1	Plot treatment (same as card #1)
2	I1	Chamber position - Column (see Figure 16)
3	I1	Chamber position - Row 1, 2, or 3 (see Figure 16)
		Atmometer water loss - white (ml/day) in:
5-9	F5.2	Quadrant 1=north
11-15	F5.2	Quadrant 3=south
17-21	F5.2	Quadrant 5=center
		Atmometer water loss - black (ml/day) in:
23-27	F5.2	Quadrant 1=north
29-33	F5.2	Quadrant 3=south
35-39	F5.2	Quadrant 5=center
		Atmometer water loss - difference black minus white (ml/day) in:
41-45	F5.2	Quadrant 1=north
47-51	F5.2	Quadrant 3=south
53-57	F5.2	Quadrant 5=center
		Air flow (ft/min) in:
59-61	I3	Quadrant 1=north
63-65	I3	Quadrant 3=south
67-69	I3	Quadrant 3=center
80	I1	Image sequence, 7 for Card #7

Missing Data--

No missing data.

The sample presented here is 2 units, 1 to 2, of 63 units included in data set C9A2.

111	111.7	194.2	166.8	175.3	123.2	175.7	169.1	166.1											1
111	67.1	90.3	98.6	110.2	80.9	93.4	103.0	102.3											2
111	56.0	91.8	67.5	56.0	106.6	80.1	72.8	61.4											3
111	234.8	376.3	332.9	341.5	310.7	349.2	344.6	329.8											4
111	14.1	14.0	13.9	14.2	14.4	24.2	24.1	22.8	24.2	23.0									5
111	28.3	28.7	28.6	28.6	28.5	11.6	11.7	11.6	11.6	11.6									6
111	9.26	9.09	8.93	13.50	12.32	12.87	4.24	3.32	3.94	40	73	75							7
212	104.5	216.3	239.9	130.6	145.9	224.9	222.4	133.8											1
212	111.7	152.9	152.3	129.7	136.8	148.4	140.5	129.8											2
212	79.2	84.0	100.3	72.2	98.7	91.5	97.4	95.2											3
212	295.4	453.2	492.5	332.5	381.4	464.8	460.3	358.8											4
212	13.8	13.2	13.7	13.6	14.1	21.4	21.9	21.4	21.4	21.4									5
212	28.4	28.6	28.4	28.9	28.5	11.9	12.1	11.9	11.9	11.8									6
212	9.49	8.75	9.60	12.61	12.26	14.39	3.12	3.51	4.79	18	23	23							7

Objectives--

Chamber Sites--

165

Alfalfa was selected because its low growth habit caused little restriction to air flow in the chambers, thus permitting uniform distribution of air pollutants throughout the plant canopy.

Nine identical plots, three plots with charcoal filter chambers, three plots with chambers without filters, and three plots without chambers were established in the field using a Latin-square design with plots 6.1 m apart.

Chambers were placed in the field and the fans were started on 13 April 1976, when the alfalfa in all plots was approximately 5.0-7.5 cm high. The plots were treated with Kerb herbicide on 17 April to kill the grasses (principally timothy and quackgrass) within each plot.

Each plot was divided into quarters or quadrants comprising four equal subplot areas in northern, southern, eastern, and western directions delineated with 5.0 cm high strips of 2 mm wide aluminum. An area 0.3 m wide along the outer edge of each subsampling area adjacent to the plastic wall was marked off with the same strip.

Open Top Field Chambers--

Six cylindrical chambers, 2.4 m high by 3 m in diameter, similar in design to those detailed by Heagle (1973), were obtained. The chambers were covered with vinylchloride plastic film (Krene-KDA-2244 Union Carbide). The air-handling system, designed to filter pollutants from the ambient air and to maintain a constant air flow through the chambers at a rate sufficient to minimize the entrance of polluted air in the top, consisted of fiberglass particulate filter, squirrel-type blower, and duct leading to the perforated lower panel. The blowers were fitted with 40.6-cm fans (squirrel type) delivering 53.8 m³/min at 0.6-cm static pressure. The air entering each chamber was forced through a 50 cm diameter plastic duct into the lower double panel that enclosed the chamber. Air entered the growing area of the chamber through a large number of 2 cm holes spaced to a 1.2 m height on the inner surface of the lower plastic panel. Cylindrical chambers were used to insure uniform air flow and pollutant distribution (Heagle et al. 1973, Made et al. 1973).

Three of the six chambers were fitted with stainless steel canister filters each containing 20.5 kg of coconut shell charcoal (Barnebey-Cheney grade CH).

The charcoal filters effectiveness in removing oxidants from the ambient air was checked by monitoring oxidants in the center of the ducts leading from the blowers to the chambers with a Mast 724-1 oxidant meter. Oxidants were monitored for 20 min. in each chamber and for 20 min in the ambient air between chamber measurements on only 1 day.

Three control chambers without air filters were used to determine possible chamber effects on plant growth. The six chambers were fitted with fiberglass particulate filters 5 cm thick for dust removal.

To insure equal flow in all chambers, air flow readings were taken with an anemometer (Anemotherm Model 60) in the duct between the fan and the chamber. Air flow was balanced between chambers by removing the air duct and measuring the velocity of air at 12 positions in the ducts with the anemometer. The sensing element was positioned perpendicular to the air flow at eight equally-spaced positions around the outer area of the duct, 5 cm from the outside edge, and at four equally-spaced positions near the center of the duct 18 cm from the outside edge. The average air flow for these 12 readings was determined. Differences in air flow between chambers was corrected by altering the size of the drive pulleys on the fan. Significant corrections were necessary to equalize flow between units containing charcoal filters and those without charcoal filters. After adjustments were made the ducts were attached to each chamber.

Separation of alfalfa growing along the outer edge of the plots from that growing in the center was necessary to determine the effect of the different treatments on yield (Figure 16). The data for the outer border of the plots, i.e., within 1 ft of the edge, were not included in the analysis because of localized environmental differences along the chamber walls that influenced the yield of chamber areas but not of open areas. Plants growing next to the wall received different radiation intensities, rates of air flow, and amounts of precipitation compared to plants growing in the center of the quadrants.

Comment--

The speed of air flow through the ducts at 840 liter/min. with squirrel-cage blowers was lower than the 1,508 liter/min. obtained when axial-blade fans were used (Heagle et al. 1973). In addition, the squirrel-cage blowers resulted in non-uniform air flow through the duct with a band of lower air flow across the bottom of the ducts and a band of higher air flow across the top of the ducts. These air-flow differences could have resulted in uneven air flow into the chambers. The use of axial blade fans would have resulted in greater uniformity in air flow throughout the duct.

Balancing air-flow rates in the different chambers with the blower units separated from the chamber duct did not provide a uniform air-flow rate when the blower units and chambers were reattached. Measurements within the chambers indicated different flow rates in filtered and unfiltered chambers. Problems apparently were caused in the attempt to balance air flows when the ducts were removed from the chamber. With reattachment, air formed a back pressure against the blower because of the restriction of air flowing out of the holes in the lower chamber wall. The different fan speeds in the filtered and unfiltered chambers could have caused different pressures to develop in these two types of chambers, causing different air-flow rates after reattachment. Better equilization of air flow would have been possible if the ducts had remained attached to the chamber and measurements had been taken by placing the anemometer sensor into the ducts through small holes.

Air Temperature Measurements--

Diurnal temperature differences between chambers and open plots and temperature differences within chambers were monitored with iron-constantin #24 thermocouples shaded with aluminum foil and attached to a wooden dowel frame with four arms that positioned thermocouples 0.9 m from the center of the chamber and 38 cm above the soil surface. Five thermocouples were attached to the frame, one at the center and the others at the ends of the arms, north, south, east, and west of the center. The thermocouple leads extended to the outside of the chambers and were monitored with potentiometers. An additional reference thermocouple was positioned outside the chambers 38 cm above the soil in the center of the experimental area. The reference thermocouple readings were utilized to correct for temperature variations that occurred over the plot area during the time that successive plots were monitored.

Temperatures were measured once at each of the five quadrants in all plots at 0700 hr on July 2, at 1200 hr on Sept. 2, at 1900 hr on Aug. 19, in the light, and at 1900 hr on Sept. 20 in the dark. These provided comparison temperatures at low and high sun angles and in the dark. To verify accuracy, the thermocouples were checked in water on 30 June 1976.

Air Flow Measurements--

Air flow velocity measurements in the chambers and in an open area were taken with an Anemotherm Model 60 directional hot wire anemometer late in the afternoon on two separate days when ambient air flow over the alfalfa was low--< 6 m/min. Air flow was measured in the center, 0.9 m north of the center, and 0.9 m south of the center in each plot at positions where temperature and evaporation measurements were taken. The readings of the two measurements were averaged for each of the three positions. No calibration was performed on the anemometers because of difficulties in the calibration procedure.

In addition, a comparison of air-velocity levels at different places within a chamber was made at 15 cm intervals across one filtered chamber, just above the alfalfa canopy and 38 cm above the soil surface. These measurements are presented in Figure 17. The air flow across the chamber was measured with an Anemotherm Model 60 hot wire anemometer. Measurement positions at 15 cm intervals were marked on strings suspended across the diameter of the chamber in north-south and east-west directions. Nineteen readings were taken along each string. Readings were taken with the anemometer attached to the end of a thin bamboo pole. The sensor was attached to this assembly so that the operator could remain outside the plot. Two measurements were taken at each measurement point: first with the anemometer oriented so that the sensing wire was perpendicular to air flow in an east-west direction and then re-attached and oriented so that it was perpendicular to the air flow in a north-south direction. Difficulties in calibration occurred so the anemometer was not calibrated.

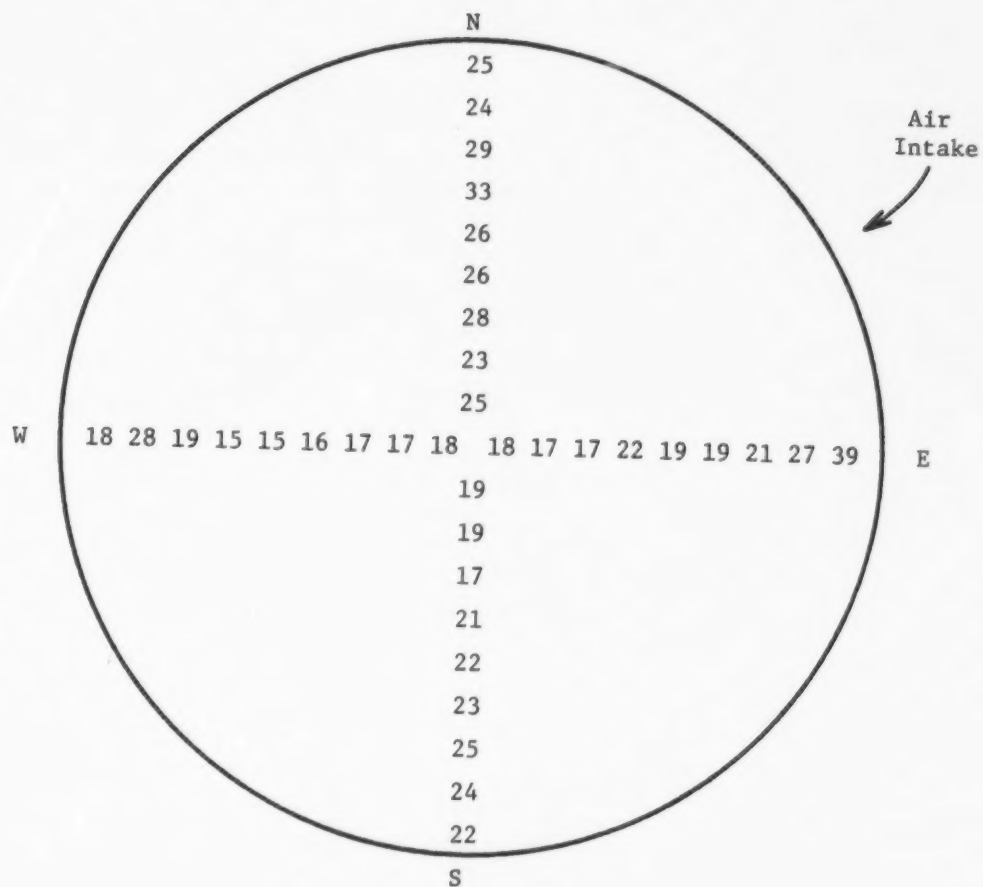


Figure 17. Air flow (m/min.) at 15-cm intervals across open-top chamber. Readings shown are with sensor orientation in the direction of each of the transects across the chamber.

Water Loss Measurements--

Rates of evaporative water loss for chambers and ambient areas were determined with white and black flat top Bellani atmometers (Kahl Scientific Instrument Company) (Tanner 1967). Three pairs of white and black atmometers were located in each plot. One pair was positioned at the center of the plot and the other two pairs were positioned 0.9 m north and south of the center point at three of the points where temperature readings were taken. At any one time, there were only sufficient atmometers to locate units in one filtered, one non-filtered, and one open area. Atmometers were left in the three plots of each replicate for 1.5 weeks with the bottles refilled and the quantity of added water recorded every 3-4 days. After three measurements were taken from each plot, the atmometers were moved to the plots of the second replicate and a similar set of three measurements was obtained. This was repeated for the third replicate. Average daily water loss for each chamber or open area was calculated. Because evaporation rates were very different over the periods of measurement for each replicate, the data for each period were corrected to the average water loss for the three periods. The correction was done by calculating the difference between the average of each period and the average of the three periods combined. The difference was added to, or subtracted from, the average of the three measurements taken from each plot, so that the average of each period would be the same.

Although the atmometers were utilized to estimate transpirational water loss from plants, it must be recognized that the evaporation from an atmometer is not directly proportional to transpiration from plants (Tanner 1967). Atmometer evaporation is controlled by the diffusion resistance of water vapor at the evaporating surface of the atmometer; however, transpiration is controlled both by the diffusion resistance of water vapor at the surface of the leaf and the stomatal and mesophyll resistances of the leaf itself. The stomatal resistance is much more important than the surface resistance for determining the loss of water from leaves (Meidner and Mansfield 1968).

Solar Radiation--

To test the assumption that the environment of the chambers is not significantly different from the ambient environment, the solar radiation inside the open top field chamber and in the outside environment were measured.

Solar radiation, measured as photosynthetic photon flux density (PPFD) (Shibles 1976), was monitored at 29 positions in one chamber at approximately hourly intervals between 0700 and 1800 on 2 days. A rigid aluminum angle iron frame with four arms (each 1.1 m long) was constructed to provide support and to permit easy movement of the light sensor. Positions were marked off at 15 cm intervals along each of the arms and the frame was positioned so that the arms extended from the center to the north, south, east, and west. A Lambda quantum sensor (LI-190S), measuring radiation in the spectrum between 400 and 700 nm, was attached to a wooden block and pushed along the frame from position to position with a thin pole from

outside the chamber. The radiation intensity at the center of an open plot area also was recorded at the time of each chamber measurement. The data presented in Table 28 are the average of the 29 measurements at different positions for the chamber environments as well as two measurements for the open field environment for each sun angle. The sun angle (a) and the azimuth angle (α) of the sun at the time of each set of PPFD readings were determined by use of the following formulae (List 1968):

$$\sin a = \sin \phi \sin \delta + \cos \phi \cos \delta \sin h; \sin \alpha = -\cos \delta \sin h (\cos a)^{-1};$$

Where: a = sun angle; α = azimuth angle; ϕ = latitude; δ = solar declination angle = $23.45 \cos ((n-175) (182.5)^{-1} 180^\circ)$; n = day of year; h = hour angle of sun = time from solar noon in hours $\times 15^\circ$. The equipment was calibrated before the experiment at the Instrumentation Systems Center, University of Wisconsin-Madison, with a carbon arc lamp as the light source.

TABLE 28. SOLAR RADIATION IN THE OPEN TOP CHAMBER AND AMBIENT ENVIRONMENTS

Sun angle	Ambient flux density ^a	Chamber flux density
2.8	4.5	5.2
7.4	11.8	14.6
15.3	26.6	41.5
17.0	36.4	51.2
26.8	71.7	83.5
28.7	70.9	84.0
32.5	77.8	93.1
37.5	107.0	121.0
39.2	105.4	132.0
39.5	91.6	132.0
41.8	102.2	148.5
42.4	107.0	141.0
46.7	131.7	153.5
48.6	127.3	154.5
48.8	138.0	162.5
52.3	150.7	166.5
55.8	159.1	180.5
56.7	167.2	177.5
56.8	166.1	176.5
59.0	173.6	177.0
59.0	176.0	185.0
66.3	192.0	199.0
66.8	190.0	203.0
69.8	214.8	215.5

^aFlux density was measured in $\text{nE} (\text{m}^2/\text{sec}^1)$.

Alfalfa Harvesting in the Chambers--

The alfalfa in each plot was harvested three times during the growing season to determine leaf injury, plant height, and yield. Harvests on 4 and 29 June were made when plants were at approximately 10% of full bloom, and a final harvest was made on 2 Sept. when plants were at approximately 50% of full bloom.

Plants were observed for necrosis, symptomatic of air-pollutant injury. The plants were scored for chlorosis resulting from environmental stress and disease and insect injury. To estimate leaf chlorosis the percentage of leaves per quadrat and the percentage of the area of the leaves that were chlorotic were determined by visual examination. These values were multiplied together to find the percentage of the leaf area/quadrat that was chlorotic.

Plant height was measured by placing a meter ruler in the center of each plot to determine average height of the alfalfa.

Alfalfa yield was measured by cutting off the plants 5 cm above the soil surface with an electric clipper and weighing the alfalfa immediately. Separate weights were obtained for the alfalfa from the center position of each of the northern, southern, eastern, and western quadrat areas. The alfalfa in the border (0.3-m wide areas along the wall) was harvested and weighed separately. For each quadrat area a weighed subsample of about 450 g was saved to determine alfalfa dry-weight for each subplot. Subsamples were dried for 7 days at 60°C in large forced-air dryers and for 1 day at 90°C in a constant-temperature oven.

Data for yield were compared with a 3 x 3 Latin-square analysis with quadrats as split plots (Steel and Torrie 1960). The Latin-square design was used so that variations in yield for the rows and columns in which the plots were located could be separated from the error variance. The data from the four quadrats in north, south, east, and west directions were included in the analysis as split plots.

Investigators--

Same as data set C9A11.

Supporting Documents

Olszyk, D.M., T.W. Tibbitts, and W.M. Hertzberg. 1980. Environment in open-top field chambers utilized for air pollution studies. *J. Environ. Qual.* 9(4):610-615.

Plant damage. In: Documentation of environmental change related to the Columbia Electric Generating Station. Institute for Environmental Studies, Reports 58, 62, 66 69, 82, 92, University of Wisconsin-Madison.

Tibbitts, T.W. In review. Impacts of air pollution near a coal-fired generation station on vegetation. U.S. Environmental Protection Agency, Cincinnati, Ohio.

DATA SET C9A31: LICHEN SAMPLING IN THE VICINITY OF THE COLUMBIA GENERATING STATION (1974-78)

Data Summary

Investigator--

S. Will-Wolf.

Abstract--

A survey of corticolous lichen communities in the vicinity of the Columbia Generating Station was conducted for bioassay of atmospheric emissions from the station. Twenty-nine wooded sites located from 5 to 64 km from the station in selected directions were sampled for lichens growing on the bark of black oak trees. The first sampling was conducted in the winter of 1974 and the second during the winter of 1978.

Dates of Research--

Winter 1974 and winter 1978.

Data Form--

Computer file containing 110 units with three card-images/unit.

Data Format

Field Description--

Card #1

<u>Column</u>	<u>Format</u>	<u>Description</u>
1-4	I4	Year
6-7	I2	Site number
9-10	I2	Direction of the sampling site from the generating station; 01=NE, 02=NW, 03=W, 04=SW, 05=SSE, 06=E
		Number of occurrences for species:
12-14	F3.1	<i>Arthonia caesia</i> (Flot.) Korbæ
16-18	F3.1	<i>Bacidea chlorantha</i> (Tuck.) Fink
20-22	F3.1	<i>Bacidea chlorococca</i> (Graewe ex. Stizenb.) Lett.
24-26	F3.1	<i>Buellia punctata</i> (hoffm.) Mass.
28-30	F3.1	<i>Buellia Schaererii</i> DeNot.
32-34	F3.1	<i>Caloplaca discolor</i> (w.11.) Fink
36-38	F3.1	<i>Candelaria concolor</i> (Dicks.) Stein
40-42	F3.1	<i>Candelaria concolor</i> var. <i>effusa</i> (Tuck.) Burnn.

44-46	F3.1	<i>Candelariella xanthostigma</i> (Ach.) Lett.
48-50	F3.1	<i>Cladonia coniocraea</i> (Florke) Spreng.
52-54	F3.1	<i>Evernia mesomorpha</i> Nyl.
56-58	F3.1	<i>Graphis Scripta</i> (L.) Ach.
60-62	F3.1	<i>Heterodermia tremulans</i> (Mull. Arg.) W. Club.
64-66	F3.1	<i>Lecanora conizaea</i> (Ach.) Nyl.
68-70	F3.1	<i>Lecanora hypoptoides</i> Nyl.
72-43	F3.1	<i>Lecanora pseudochlarotera</i> Brodo
76-78	F3.1	<i>Lecanora varia</i> (Ehrh.) Ach.
80	I1	Card image; 1 for card #1

Card #2

1-4	I4	Year
6-7	I2	Site number
9-10	I2	Direction
		Number of occurrences for species:
12-14	F3.1	<i>Lepraria membranacea</i> (Dicks.) Vain.
16-18	F3.1	<i>Lepraria neglecta</i> (Nyl.) Lett.
20-22	F3.1	<i>Opegrapha pulicaris</i> (Hoffm.) Schnal.
24-26	F3.1	<i>Parmelia aurulenta</i> Tuck.
28-30	F3.1	<i>Parmelia bolliana</i> Mull. Arg.
32-34	F3.1	<i>Parmelia caperata</i> (L.) Ach.
36-38	F3.1	<i>Parmelia flaventior</i> Stirt.
40-42	F3.1	<i>Parmelia galbina</i> Ach.
44-46	F3.1	<i>Parmelia rufecta</i> Ach.
48-50	F3.1	<i>Parmelia saxatilis</i> (L.) Ach.
52-54	F3.1	<i>Parmelia squarrosa</i> Hale
56-58	F3.1	<i>Parmelia subaurifera</i> Nyl.
60-62	F3.1	<i>Parmelia sulcata</i> Tayl.
64-66	F3.1	<i>Parmelia ulophyllodes</i> (Vain.) Sav.
68-70	F3.1	<i>Pertusaria pustulata</i> (Ach.) Duby
72-74	F3.1	<i>Physcia alpolia</i> (Ehrh.) Hampe
76-78	F3.1	<i>Physconia grisea</i> (Lam.) Poelt
80	I1	Card image; 2 for card #2

Card #3

1-4	I4	Year
6-7	I2	Site number
9-10	I2	Direction
		Number of occurrences for species:
12-14	F3.1	<i>Physcia millegrana</i> Degel.
16-18	F3.1	<i>Physcia orbicularis</i> (Neck.) Poetsch.
20-22	F3.1	<i>Physcia orbicularis</i> f. <i>Albociliata</i> (Bouly de Lesc.) Thor
24-26	F3.1	<i>Physcia orbicularis</i> f. <i>rubropulchra</i> (Neck.) Poetsch
28-30	F3.1	<i>Physcia stellaris</i> (L.) Hyl.
32-34	F3.1	<i>Physciopsis adglutinata</i> (Flk.) Choisy
36-38	F3.1	<i>Physciopsis syncolla</i> (Tuck. ex, Nyl.) Poelt
40-42	F3.1	<i>Pyrenula neglecta</i> Harris
44-46	F3.1	<i>Pyxine sorediata</i> (Ach.) Mont.

48-50	F3.1	<i>Ramalina fastigiata</i> (Pers.) Ach.
52-54	F3.1	<i>Ramalina sinensis</i> Jatta
56-58	F3.1	<i>Rinodina papillata</i> Magn.
60-62	F3.1	<i>Usnea hirta</i> (L.) Wigg.
64-66	F3.1	<i>Xanthoria fallax</i> (Hepp.) Arn.
80	I1	Card image; 3 for card #3

Missing Data--

No missing data.

Data Sample

The sample presented here are 3 units, 7 to 9, of 330 units included in data set C9A31.

123456789012345678901234567890123456789012345678901234567890																				
1974	02	01	10.	3.	2.	0.	0.	0.	0.	5.	0.	0.	0.	1.	0.	0.	0.	4.	0.	1
1974	02	01	0.	2.	4.	5.	0.	4.	0.	2.	9.	0.	1.	0.	1.	0.	1.	2.	0.	2
1974	02	01	10.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	6.	0.	0.	0.	0.	0.	3
1978	02	01	8.	0.	0.	0.	1.	0.	1.	4.	0.	0.	0.	1.	0.	1.	2.	5.	0.	1
1978	02	01	0.	1.	1.	3.	0.	5.	0.	0.	8.	0.	0.	0.	3.	0.	1.	0.	0.	2
1978	02	01	8.	1.	0.	0.	2.	0.	0.	1.	0.	0.	0.	4.	0.	0.	0.	0.	0.	3
1974	02	02	10.	4.	6.	0.	1.	0.	0.	2.	0.	0.	0.	5.	0.	0.	0.	5.	0.	1
1974	02	02	0.	1.	2.	7.	0.	2.	0.	1.	8.	0.	0.	0.	0.	0.	2.	0.	0.	2
1974	02	02	8.	4.	0.	2.	1.	0.	1.	0.	0.	0.	0.	6.	0.	0.	0.	0.	0.	3

Quality Assurance

Objectives--

This project was designed to study lichen communities for bioassay of atmospheric pollutants in the vicinity of the Columbia Generating Station.

In general, lichens are more susceptible than vascular plants to SO₂ because of their ability to absorb moisture from the air. Since there was no knowledge of indicator species, this study approaches the problem by studying changes at the community level.

Sampling Sites--

The sampling sites were located along compass radii (Figure 18). The differing lengths of the radii correspond to the differing frequency of wind directions. Along southeast, east, northeast, north-northeast, and west radii, 29 sampling sites were selected at 3, 6, 10, 20, and 30 miles (4.8, 9.6, 16, 32, and 48 km) from the Columbia power plant. Along the south-west radius, sites were chosen at 3, 6, and 10 miles (4.8, 9.6 and 16 km) from the power plant. Along the east radius, one site was located 40 miles (64 km) from the power plant.

Sampling Procedure--

Ten black oak trees at each study site were selected for lichen sampling (see data set C9A32). The exact locations of the trees were

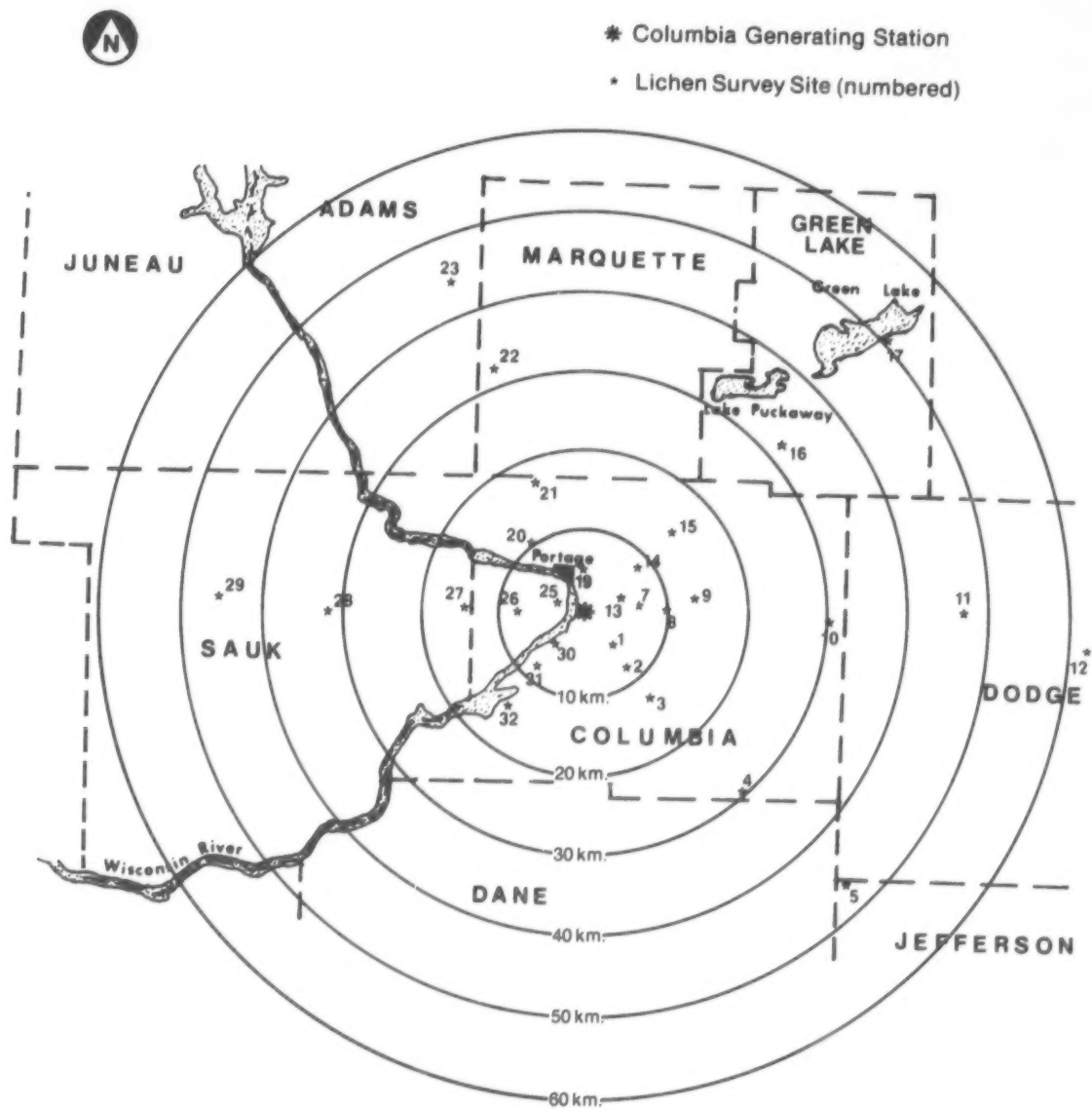


Figure 18. Location of lichen monitoring sites around the Columbia Generating Station.

documented and maps are available from the data center upon request. Tree size was measured at 4.5 ft above ground using a tape marked for conversion of circumference to basal area in square inches. An effort was made to select trees whose basal area was between 100 and 300 in². No trees smaller than this were sampled, though in some cases larger trees had to be used.

For each tree, one bark quadrant was established on the northeast-facing side and another on the side facing the generating station. The center of each quadrant was placed 4.5 ft above the ground. The direction of the second quadrant varied for each transect. All trees were sampled on the northeast side to allow equal comparison between sites.

Effects of SO₂ emissions are known to vary with aspect (direction the object faces) and are greatest on the side of a tree facing the pollution source (Newberry 1974). Therefore, bark quadrants facing the generating station appeared to be the most likely sites for lichen damage. For sites on the southwest transect, both sets of quadrants coincided, so only one quadrant/tree was sampled.

On each tree, an aluminum nail was placed in the upper left corner of the 25-cm² quadrant to be sampled. A numbered aluminum tag was hung from the nail marking the northeast bark quadrant on each tree. During the second phase of the study (winter 1978), the tagged trees were identified and the lichens were sampled from the closest black oak tree.

The same sampling procedure was used in both phases. The outer bark was removed from the sample quadrant with hammer and wood chisel, with care taken not to injure the inner bark of the tree. All visible lichens, plus large pieces of bark, were removed for microscopic examination. Tree bark was collected in 5-lb paper bags. Each bag was identified in the field by site, date, tree number, and quadrant aspect.

Lichen Identification--

Forty-six species of lichens were identified from the black oak bark samples collected in the study. Bark samples were examined under a dissecting microscope and the presence of lichen species was tallied for each quadrant. Lichens were identified using Hale (1969) and B. Fink (1935); unpublished keys; and personal identification by Dr. John W. Thomson from the University of Wisconsin-Madison for crustose lichens.

Investigator--

The study was designed and executed by Susan Will-Wolf. Susan Will-Wolf received her Ph.D. from the University of Wisconsin-Madison (1975) in Botany and Zoology with a specialization in ecological effects.

Supporting Documents

Will-Wolf, S. 1975. Lichen for bioassay of SO₂ emissions. Institute for Environmental Studies, University of Wisconsin-Madison.

Will-Wolf, S. 1980. Structure of corticolous communities before and after exposure to emissions from a "clean" coal-fired generating station. The Bryologist 83(3):281-295.

Will-Wolf, S. 1980. Effects of a "clean" coal-fired generating station on four common Wisconsin lichen species. The Bryologist 83(3):296-300.

DATA SET C9A32: TREE SAMPLING IN THE LICHEN STUDY

Data Summary

Investigator--

S. Will-Wolf.

Abstract--

This data set contains the results of a tree survey carried out during the winter and spring of 1974 concurrent with the lichen study (data set C9A31). At each of the 29 sites of the lichen sampling, 20 sample plots (0.01 ha in size) were established, and were sampled for all species of trees > 15 cm in diameter. The data for each site contain the number of sample plots at which each tree species occurred, total number of sampled trees of each species, summed basal area (in²) of all sampled trees of a species, percent frequency of a species, percent density, percent dominance, Importance Values, Clarex Adaptation Value, and Continuum Index.

Dates of Research--

Winter 1974.

Data Form--

Computer file containing 148 units with one card-image/unit.

Data Format

Field Description--

<u>Column</u>	<u>Format</u>	<u>Description</u>
1-2	I2	Site number
4-35	5(A6),A2	Genus; species name
37-38	I2	Species identification (see Table 29)
40-43	F4.1	Climax adaptation value
45-46	I2	No. of points species occurred
48-49	I2	No. of trees in this sample
51-54	I4	Summed basal areas of sampled trees
56-59	F4.1	Percent frequency
61-64	F4.1	Percent density
66-69	F4.1	Percent dominance

71-74 F4.1 Importance value
76-80 F5.1 Continuum index

Missing Data--

Not applicable.

TABLE 29. CODE FOR SPECIES NAMES

Identification number	Species	Identification number	Species
01	<i>Acer Negundo</i>	15	<i>Pinus Strobus</i>
02	<i>Acer Rubrum</i>	16	<i>Populus Grandi</i>
03	<i>Acer Saccharinum</i>	17	<i>Populus Tremuloides</i>
04	<i>Acer Saccharum</i>	18	<i>Prunus Serotina</i>
05	<i>Betula Papyrifera</i>	19	<i>Quercus Alba</i>
06	<i>Carya Cordiformis</i>	20	<i>Q. Ellipsoidalis</i>
07	<i>Carya Ovata</i>	21	<i>Q. Macrocarpa</i>
08	<i>Celtis Occidentalis</i>	22	<i>Q. Rubra</i>
09	<i>Fraxinus Americana</i>	23	<i>Q. Velutina</i>
10	<i>Juglans Cinera</i>	24	<i>Robinia Pseudoacacia</i>
11	<i>Juniperus Virginiana</i>	25	<i>Romina Pseudoacacia</i>
12	<i>Morus Rubra</i>	26	<i>Tilia Amer.</i>
13	<i>Ostrya Virginiana</i>	27	<i>Ulmus Amer.</i>
14	<i>Pinus Resinosa</i>	28	<i>Ulmus Rubra</i>

Data Sample

The sample presented here are 10 units, 1 to 10, of 148 records included in data set C9A32.

123456789012345678901234567890123456789012345678901234567890

01 CARYA OVATA	07	4.5	2	2	32	5.4	3.2	0.5	3.0	13.5
01 PRUNUS SEROTINA	18	3.5	10	25	1301	27.0	39.7	20.5	29.1	101.8
01 Q. ALBA	19	3.5	6	8	1905	16.2	12.7	30.7	19.9	69.6
01 Q. MACROCARPA	21	1.0	13	20	1358	35.1	31.8	21.4	29.4	29.4
01 Q. VELUTINA	23	2.5	6	8	1705	16.2	12.7	26.9	18.6	46.5
02 ACER RUBRUM	02	7.0	5	12	629	12.5	17.6	9.0	13.0	91.0
02 PRUNUS SEROTINA	18	3.5	6	10	344	15.0	14.7	4.9	11.5	40.2
02 Q. ALBA	19	3.5	15	25	2943	37.5	36.8	42.0	38.8	135.8
02 Q. MACROCARPA	21	1.0	2	3	265	5.0	4.4	3.8	4.4	4.4
02 Q. VELUTINA	23	2.5	12	18	2828	30.0	26.5	40.4	32.3	80.8

Quality Assurance

Objectives--

The goal of this study was to compare the lichen study sites to each other and to the range of natural vegetation found in southern and central

Wisconsin. The tree sampling data provided a measure of the variation in sampling sites, revealing any unusual sites that could confuse the analysis of the lichen data.

Sampling Sites--

Same as data set C9A31.

Sampling Procedure--

Twenty sampling plots 0.025-acre in size (radius 18 ft) were established at each site using a range-finder and were sampled for all species of trees > 6 in. in diameter. Sampling plots were centered on points at 50-ft intervals along compass lines. There were five points along these compass lines, creating a 250 x 200 ft grid.

Investigator--

Same as data set C9A31.

Supporting Documents

Same as data set C9A31.

DATA SET C9A41: TIPBURN INJURIES TO EASTERN WHITE PINE NEAR THE COLUMBIA GENERATING STATION (1977-78)

Data Summary

Investigators--

D.F. Karnovsky and T.W. Tibbitts.

Abstract--

An 8-yr survey (1971-78) of eastern white pine in the vicinity of the Columbia Generating Station was conducted to evaluate the changes in tipburn injuries as the result of atmospheric emissions from the Columbia Generating Station. Fifteen sites, located 0.8 to 12.1 km from the site in selected directions were sampled in the fall of each year.

Dates of Research--

1971-1978.

Data Form--

This data set contains 15 units with one card image/unit.

Data Format

Field Description--

<u>Column</u>	<u>Format</u>	<u>Description</u>
1-2	I2	Site number
4-5	I2	Stand age (years)
7-9	I3	Stand age (years) of the second stand ^a
11-13	I3	Number of trees in each sample
15-16	I2	Number of trees with tipburn injuries, 1971
18-20	F3.1	Tipburn frequency--percent trees injured, 1971
22-23	I2	Number of trees injured, 1972
25-28	F4.1	Tipburn frequency, 1972
30-31	I2	Number of trees injured, 1973
33-36	F4.1	Tipburn frequency, 1973
38-39	I2	Number of trees injured, 1974
41-44	F4.1	Tipburn frequency, 1974
46-47	I2	Number of trees injured, 1975
49-52	I2	Tipburn frequency, 1975
54-55	I2	Number of trees injured, 1976
57-60	F4.1	Tipburn frequency, 1976
62-63	I2	Number of trees injured, 1977
65-68	F4.1	Tipburn frequency, 1977
70-71	I2	Number of trees injured, 1978
73-76	F4.1	Tipburn frequency, 1978

Data Sample

The sample presented here contains 15 units, the complete data set C9A41.

1234567890123456789012345678901234567890123456789012345678901234567890

1	15	40	355	99	999	7	2.0	16	4.5	8	2.2	20	5.7	5	1.4	8	2.3	10	2.8
2	20	999	100	99	999	3	3.0	8	8.0	14	14.0	4	4.0	3	3.0	2	2.0	8	8.0
3	20	10	199	99	999	0	0.0	0	0.0	0	0.0	3	1.2	2	1.0	1	0.5	6	3.0
4	35	999	20	1	5.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1	5.0
5	25	999	141	99	999	3	2.1	2	1.4	6	4.3	4	2.8	0	0.0	7	3.5	22	15.6
6	15	999	76	6	7.9	3	3.9	2	2.6	2	2.6	4	5.3	1	1.3	3	3.9	4	5.3
7	15	999	30	99	999	2	6.7	2	6.7	0	0.0	2	6.7	0	0.0	0	0.0	7	23.3
8	15	999	50	99	999	4	8.0	3	6.0	1	2.0	1	2.0	0	0.0	1	2.0	2	4.0
9	35	999	114	9	7.9	2	1.8	1	0.9	0	0.0	12	10.5	0	0.0	9	7.9	31	27.4
10	20	999	62	99	999	1	1.6	1	1.6	1	1.6	1	1.6	1	1.6	1	1.6	1	1.6
11	15	999	77	99	999	0	0.0	0	0.0	0	0.0	3	3.9	0	0.0	0	0.0	2	2.6
12	20	999	27	0	0.0	0	0.0	2	7.4	2	7.4	1	3.7	0	0.0	2	7.4	3	11.1
13	15	999	100	3	3.0	2	2.0	6	6.0	1	1.0	6	6.0	0	0.0	4	4.0	4	4.0
14	20	999	41	3	7.3	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1	2.4	4	9.8
15	20	999	138	3	2.2	1	0.7	1	0.7	2	1.4	6	4.3	1	0.7	0	0.0	0	0.0

¹²Plots with age shown on column 7-9 are made up of two stands with ages shown.

Quality Assurance

Objectives--

The objective of this study was to monitor the effect of air pollution from a coal-fired power plant on vegetation. Eastern white pine (*Pinus strobus* L.) was chosen as a forest-bioindicator species for this study of the environmental impact of the Columbia Generating Station because of its sensitivity to SO₂ and its widespread occurrence in the area surrounding the power plant.

Sampling Sites and Procedure--

To study the effect of the air pollution emitted by the Columbia Generating Station, 15 permanent sample plots, located in stands of eastern white pine near the power plant, were monitored for 8 yr. The study began in the 1971 growing season 4 yr before the generating station began operations.

White pines were selected for monitoring in 1971. Aerial photos of Columbia County were obtained from the Agricultural Stabilization and Conservation Service of the U.S. Department of Agriculture to locate white-pine stands surrounding the power-plant site. Most stands were selected directly from these photos following ground verification. Stands near high-voltage power lines, near houses, or with unusual exposure were avoided whenever possible. Stands near roads were especially avoided because of the possibility of injury from road salting. Stands were generally chosen that were characterized by accessibility, exposure to wind from at least one direction, and a minimum likelihood of being cut down or altered in the near future. The 15 suitable sites were selected to provide a random sampling of the area in all directions within a 13-km radius of the generating station (Figure 19 and Table 30).

Monitoring Procedure--

At sites with < 100 trees, all the trees were monitored. At the larger sites, trees were monitored if their position could be accurately documented and if they could be observed from the base to the tip on at least one side. Thus, trees in rows and particularly those on outside rows were commonly selected for monitoring. The position of each tree to be sampled was documented. Identification was achieved by attaching a label to the first tree in each row and then numbering all the trees in each row. The locations of the trees were documented on maps. Copies of these maps are available from the data center.

Foliar injury was examined annually on each tree to determine the presence or absence of tipburn. For each tree, symptoms of air-pollutant injury were differentiated from those caused by other types of environmental stress, disease, insects, or human activities. Trees with air-pollutant injury were recorded. Each tree was examined annually between late Sept. and early Oct. In response to reports by local residents of noticeable

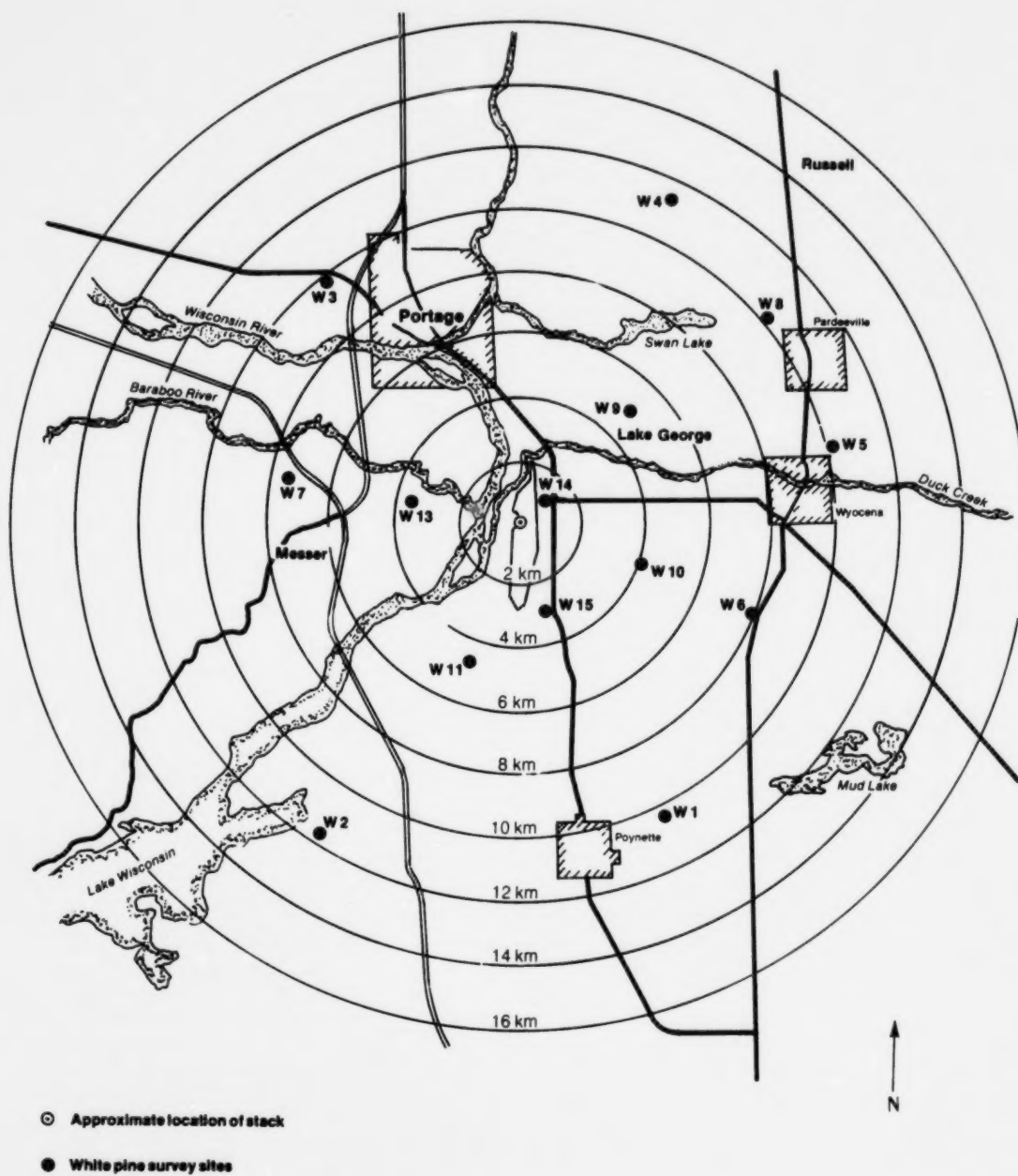


Figure 19. Location of white pine sampling sites around the Columbia Generating Station.

TABLE 30. DESCRIPTION OF WHITE-PINE MONITORING SITES

Site	Distance from generating station (km)	Approximate age of the stand (yr)	Number of trees sampled	Exposure ^a
1	11.3 SSE	15,40 ^b	355	open
2	10.5 NW	20	100	closed
3	12.1 NE	10,20 ^b	199 ^c	open
4	10.5 E	35	20	open
5	8.1 EE	25	141	open
6	7.2 SW	15	76	closed
7	8.1 WNW	15	30	open
8	8.9 NE	15	50	open
9	4.8 NE	35	114	open
10	4.4 SE	20	62	closed
11	4.8 SSW	15	77	open
12	3.2 SW	20	27	open
13	4.0 NW	15	100	closed
14	0.8 NW	20	41	open
15	2.8 NW	20	138	closed

^aOpen sites have trees exposed fully to the wind from at least one direction. Underlining indicates sites open toward the generating station.

^bThese plots are made up of two stands with the ages shown.

^cSite 3 had 242 trees before a fire in 1976.

white-pine injury, partial surveys were made during the summers of 1975 and 1977. In 1976, a fire destroyed a portion of the 242 trees located at monitoring site 3. A complete resurvey was made in June 1978 because of the high frequency and severity of injury at two sites.

During the June 1978 survey, samples of white pine needles were obtained from several sites for S analysis. Samples were taken from the midcrown to upper crown of two to four white pines from sites 2, 4, 5, 6, 7, and 9. The needles were sent to Dr. C. Gordon of the Univ. of Montana for S analysis. Separate analyses were conducted on needles that had developed in 1976, 1977, and 1978. The data are presented in Table 31.

Investigators

The investigation was conducted by D. Karnovsky. At the time of the study, he was working toward a Ph.D. degree in Horticulture at U.W.-Madison under the supervision of Dr. T.W. Tibbitts.

Supporting Documents

Same as data set C9A1.

TABLE 31. SULFUR CONTENT (ppm) OF WHITE PINE NEEDLES
HARVESTED IN 1978 FROM SELECTED SAMPLING SITES

Site	Tree sampled	Year of needle growth			
		1977	1976	1975	1974
2	A	1,450	1,050	1,100	1,000
	B	1,350	1,150	950	
4	A	1,200	1,300	950	
	B	1,200	700	600	
5	A	1,200	1,250	900	
	B	1,200	1,050	850	
	C	1,150	1,350	1,150	
	D	950	950	1,100	
6	A	1,450	1,450	1,150	
	B	1,200	1,050	1,050	
7	A	1,450	1,550		
	B	1,150	1,200		
9	A	1,550	1,550		
	B	1,300	800		

DATA SET C9A42: SITE MAPS FOR THE WHITE PINE STUDY

Data Summary

Investigators--

D.F. Karnovsky and T.W. Tibbitts.

Abstract--

This data set contains the maps of the white pine study sites (data set C9A41). Each of the 15 sites are documented in 2 maps. The first shows the exact location of the sampling sites on elaborated township maps. The second maps shows each site in detail and the relation of the sampling location to trees, posts, and fence lines. Changes in site location also are documented.

Dates of Research--

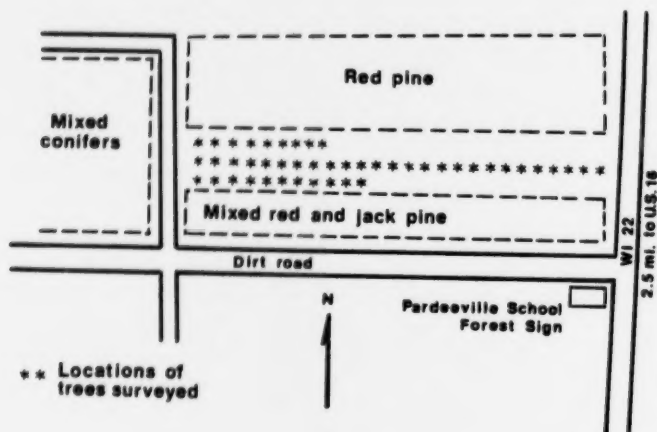
1971.

Data Form--

This data set includes 6 township maps and 16 maps of the sites.

Data Sample

The following sample presents one of the 15 site maps included in data set C9A42. No sample is presented of the township maps which also are included in this data set.



Quality Assurance

Objectives--

The purpose for preparing these maps was to provide a record of the exact locations of the white pine sampling sites.

Sampling Sites--

Same as data set C9A41.

Preparatory Procedures--

The township maps were copied from the 1972 Rockford Map Atlas. The detailed site maps were hand drawn and show the exact location of the site as well as the relationship of the site to trees, posts, and fence lines, but not to scale.

Investigators--

Same as data set C9A41.

Supporting Documents

Same as data set C9A1.

DATA SET C9B1: OZONE MONITORING AT THE MESSER SITE OF THE COLUMBIA
GENERATING STATION (1976-78)

Data Summary

Investigators--

T.W. Tibbitts, J. Kobriger, H. Frank, and D. Olszyk.

Abstract--

Hourly-average records of O_3 ($\mu g/m^3$) were collected from the Messer site located 7.0 km west of the Columbia Generating Station. Ozone was monitored continuously from May 1976 to December 1978, and the average data recovery for the period was 86.7%.

Dates of Research--

12 May 1976-31 December 1978.

Data Form--

Computer file containing 1,220 units with one card-image/ unit.

Data Format

Field Description--

The following field description is for data sets C9B1, C9B2, and C9B3. It is in accordance with the U.S. EPA Storage and Retrieval of Aeromatic Data (SAROAD).

<u>Column</u>	<u>Format</u>	<u>Description</u>
1-3	I3	State code; 151-Wisconsin
4-7	I4	Location; 0600-Columbia County
8-10	I3	Site; 003=Lake George, 005=Messer, 008=Genrich
11	A1	Funding agency type; F=state
12-13	I2	Project classification; 02=source-oriented ambient surveillance
14	I1	Time interval; 1=1 hr
15-16	I2	Year
17-18	I2	Month
19-20	I2	Day
21-22	I2	Hour of first measurement
23-27	I5	Parameter code; 44201=ozone (C9B1), 42601=nitrous oxide (C9B2), 42602=nitrogen dioxide (C9B2), 42603=total nitrogen oxides (C9B2), 44101=total oxidants (C9B3)
28-29	I2	Method code; 14=chemiluminescent; 81=colormetric
30-31	I2	Units of data; 01= $\mu g/m^3$ (@ 25°C, 1013 mb)

Decimal point locator columns from right
Hourly observations

Missing data are indicated by 9999.

The sample presented here is 10 units, 1 to 10 out of 1,220 units included in data set C9B1.

[illegible]

Objectives--

The purpose of the study was to monitor O₃, which is present as a background pollutant in the atmosphere, near the Columbia Generating Station. The O₃ monitoring replaced the oxidant monitoring (data set C9B3) that was carried out from 1973 to 1977. Additional O₃ monitoring is documented in data set C17A2.

Monitoring Site--

The monitoring was carried out at the Messer site located 7.1 km west of the Columbia Generating Station on the Baraboo Hills at an elevation 390 m above MSL (Figure 20). This site was relatively unaffected by the power plant.

Equipment--

Ozone was monitored with a Monitor Labs Incorporated model number 8410A Ozone Analyzer that detects O_3 by gas phase chemiluminescence. The operation of this instrument is based on the chemiluminescence of an activated molecular aldehyde species produced by a reaction between O_3 and ethylene.

Specifications of interest:

Range used: 0.2 ppm
Precision: $\pm 1\%$ full scale

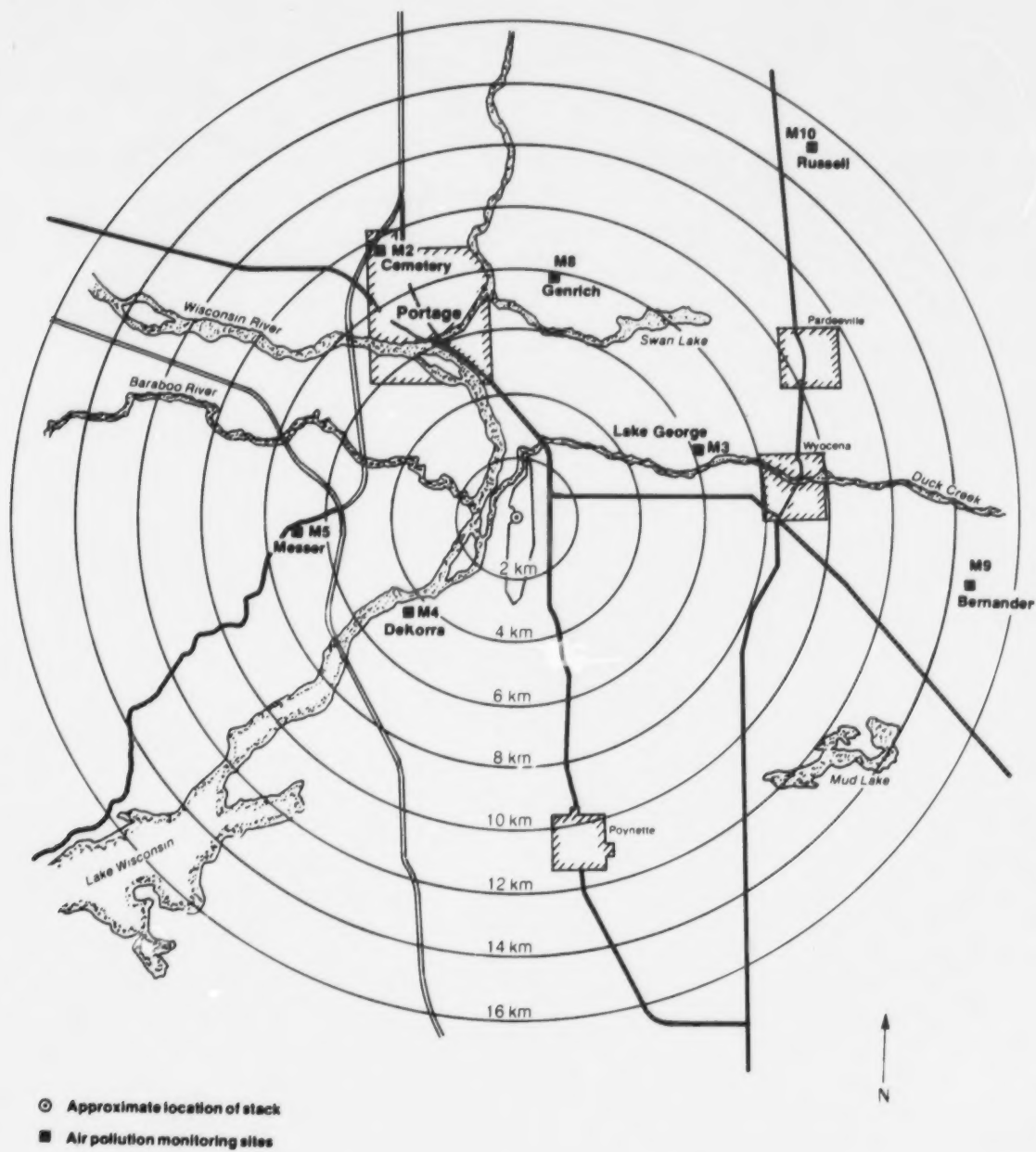


Figure 20. Location of air pollution monitoring sites around the Columbia Generating Station.

Minimum detectable concentration: (1) 2 ppb and (2) 0.33 ppb based on two

STD of noise

Zero stability: > 4 ppb/24 hr

Span stability: > $\pm 1\%$ /day or $\pm 2\%$ /14 days

Linearity: $\pm 1\%$ full scale

The data were continuously recorded with Leeds & Northrup Speedomax W/L recorders.

Calibration and Analyzer Checks--

The analyzer was calibrated with a multipoint check at monthly intervals and with a span and zero check at weekly intervals using a portable calibrator, Monitor Labs 8500 Permacal. Calibration information was recorded on the recorder chart. Twice weekly, the analyzer was checked for satisfactory operation and the chart marked with time and date.

The Permacal was calibrated at 3-month intervals at the Wisconsin State Laboratory of Hygiene with the Neutral Buffered Potassium Iodide (NBKI) wet-chemistry procedure. A comparison check was made by auditing the lamp output with a chemiluminescent O_2 analyzer that was calibrated by a Bendix 8861D gas titrator. The Permacal was calibrated more frequently if there was any uncertainty about the calibration made with field analyzers. Permacal rotometers were calibrated every 3 months using a wet-test-meter and soapbubble-flowmeter traceable to NBS.

Data Reduction--

The data reduction procedure was as follows:

- (1) For the period between two multipoint calibrations, the chart was unrolled and:
 - (A) Times marked by the field technician were compared to times printed on the recorder chart. If there were discrepancies, reasons for incorrect times could be determined, correct times were penciled onto chart. If discrepancies could not be determined, the data was discarded for the period showing incorrect times.
 - (B) The chart was divided into periods beginning and ending at noon on days that had a zero in the data. A span check was usually made at 1 week intervals. Unless there were indications printed on the chart by the field technician that certain data might be incorrect, the data for the period was assumed to be valid. If information indicated that the data might be questionable, it was processed, but not reported unless the questions were satisfied.

(2) For each time period:

- (A) An average zero reading in terms of chart units was calculated for each period by taking the average of the analyzer zero readings at beginning and end for each time period. (If there was an analyzer zero reading for midway between span checks, it is included in the average).
- (B) An average span reading in terms of chart units was calculated for the period by taking average of span readings at the beginning and end of each time period.
- (C) If a multipoint calibration was made at the beginning or end of a period, the calibration point was the same as the corresponding (end or beginning) span point for that period.
- (D) The average location for zero and span readings at the beginning and end of each period was noted in pencil on the chart.

(3) Analysis of chart with digitizer:

- (A) The chart was unrolled and lines were drawn with a ruler through the fluctuating recordings for each hourly interval. The midpoint of each line was accepted to be the average value for that hourly interval.
- (B) The chart was unrolled across the 1.37 m width of the digitizer and secured with tape.
- (C) Computer cards were prepunched with identification information, date and time, and then punched using the digitizer with the location of zero reading, span reading, and average hourly reading.
- (D) Steps (B) and (C) were repeated until entire chart was digitized.

(4) Adjustment of data:

- (A) Computer cards were separated for each time period between two multipoint field calibrations. The concentrations of pollutants for each hourly interval were calculated and punched on cards. This was obtained by the following formula:

$$x = \left(\left(y \left(\frac{\text{Average Hourly Reading} - \text{Zero Reading}}{b} \right) \left(\frac{\text{Span Reading} - \text{Zero Reading}}{a} \right) - a \right) z \right) \quad (4)$$

where x = hourly average in $\mu\text{g}/\text{m}^3$; y = span reading in ppm; z = conversion factor for a pollutant in $\mu\text{g}/\text{m}^3/\text{ppm}$; a = average y intercept from the beginning and end multipoint calibrations; and b = average slope from beginning and end multipoint calibrations.

- (B) Data was validated by two methods: spot calculations of 1 hour each day comparing chart readings to printed out values on computer cards; and by making a computer plotting of calculated hourly values, and then examining the plotting for hourly values that deviated significantly from each daily pattern.

Data Recovery--

The data recovery for the entire period of study was 86.7% valid measurements out of 23,400 possible measurements in data set C9B1.

Investigators--

The study was carried out by J. Kobriger, H. Frank, and D. Olszyk. J. Kobriger and D. Olszyk were studying toward Ph.D. degrees in Horticulture. H. Frank, a technician, was responsible for the equipment. The study was carried out under the supervision of T.W. Tibbitts who is a Professor in the Horticulture Department at the University of Wisconsin-Madison.

Supporting Documents

Same as data set C9A11.

DATA SET C9B2: NITROGEN OXIDES (NO, NO₂, NO_x) MONITORED NEAR THE COLUMBIA GENERATING STATION (1976-78)

Data Summary

Investigators--

T.W. Tibbitts, J. Kobriger, H. Frank, D. Olszyk.

Abstract--

Hourly-average records of NO, NO₂, and total NO_x in $\mu\text{g}/\text{m}^3$ were collected from 1 March 1976 through 11 June 1976 at the Lake George site located 6.2 km east of the Columbia Generating Station. Data were collected from 12 June 1976 through 31 Dec. 1978 at the Genrich site located 8.3 km north of the Generating Station. Data recovery for the period was 56.0%.

Dates of Research--

March 1976-December 1978.

Data Form--

The data are stored in three computer files, one for each measurement. Each file contains 1,342 units with one card-image/unit.

Data Format

See data set C9B1.

Data Sample

See data set C9B1.

Quality Assurance

Objectives--

The purpose of this study was to monitor the nitrogen oxides emitted by the Columbia Generating Station.

Monitoring Site--

Nitrogen oxides were collected from 1 March 1976 through 11 June 1976 at the Lake George site located 6.2 km east of the Columbia Generating Station (Figure 19). When the Genrich site was built the equipment was transferred to the Genrich site on 12 June 1976. The Genrich site is located 8.3 km north of the generating station.

Sampling Equipment--

Nitrogen oxides were monitored with a Monitor Lab Incorporated 8440 analyzer that employs a dual channel chemiluminescent system to provide simultaneous measurements of NO, NO₂ and total NO_x.

Specification of interest:

Recording range: 0-0.2

Detection limit: 2 ppb for NO, NO₂, NO_x

Repeatability: ± 1% NO and NO_x output
± 1.4% NO₂ output

Calibration--

Nitrogen oxide analyzers were calibrated in accordance with the Federal Reference Method at 2-month intervals or less using a Bendix 8861D gas phase titrator modified to U.S. EPA guidelines for gas titration units, and a NBS NO cylinder to produce known NO concentrations. The analyzers were given a span and zero check at weekly intervals utilizing a Monitor Labs 8500 Permecal calibrator, with a NO₂ permeation tube. Span and zero checks were recorded on the chart. The analyzers were checked twice weekly for satisfactory operation and the chart was marked with time and date. The accuracy of the NO calibration performed on the analyzer was checked by comparison to NO₂ concentrations obtained with an NBS NO₂ permeation tube at the Wisconsin State Laboratory of Hygiene. The NO₂ permeation tube was calibrated quarterly using a sodium arsenite wet-chemistry procedures.

The Permacal calibration instrument was calibrated at intervals of 3 months or less. The NO₂ permeation rate was determined by a sodium arsenite wet-chemistry procedures and the rotometers were calibrated using a wet test meter and soap-bubble flowmeter traceable to NBS. The Permacal calibration was checked with a recently calibrated NO_x analyzer.

Data Reduction--

Same as data set C9B1.

Data Recovery--

The data recovery for the entire period of study was 56.7% valid measurements out of 74,592 possible measurements in data set C9B2.

Investigators--

Same as data set C9B1.

Supporting Documents

Same as data set C9B1.

DATA SET C9B3: OXIDANTS MONITORED NEAR THE COLUMBIA GENERATING STATION (1973-77)

Data Summary

Investigators--

T.W. Tibbitts, H. Frank, D. Olszyk.

Abstract--

This data set contains hourly-average records of oxidants ($\mu\text{g}/\text{m}^3$) measured from March 1973 through September 1977. The data were collected at the Messer site located 4.4 miles west of the Columbia Generating Station.

Dates of Research--

May 1973-December 1977.

Data Form--

Computer file containing 3,226 units with one card-image/unit.

Data Format

See data set C9B1.

Data Sample

See data set C9B1.

Quality Assurance

Objectives--

The purpose of the study was to monitor oxidants, which are present as a background pollutant in the atmosphere, near the Columbia Generating Station.

Monitoring Site--

See data set C9B1.

Equipment--

Oxidants were monitored with a Model #724-2 oxidant monitor, manufactured by the Mast Development Company to detect oxidants colometrically. The monitoring procedure is based on the oxidation-reduction of a KI solution. Metered solution comes into contact with a metered air sample and an electrode. The chemical reaction that takes place between a molecule of oxidants in the air sample and the sensing solution on the electrode results in a flow of electrons through the external detection-circuits. Thus, the rate of electron flow, or current, is directly proportional to the concentration of oxidant molecules/unit of time entering the sensor. The output of the monitor was recorded continuously on strip charts with a Leeds & Northrup Speedomax W/L recorder.

Data Recovery--

The data recovery for the entire period of study was 59.8% valid measurements out of 38,736 possible measurements in data set C9B3.

Investigators--

Same as data set C9B1.

Supporting Documents

Same as data set C9B1.

SECTION 10

AQUATIC INVERTEBRATES

This subproject was designed to investigate the impact of the Columbia Generating Station on the aquatic invertebrates near the power plant site. This investigation was interrelated with investigations in two other subprojects, Trace Elements and Aquatic Chemistry.

The principal goal was to document changes in aquatic-invertebrate community composition and changes in aquatic-invertebrate life cycles caused by construction and operation of the Columbia Generating Station.

Specific objectives were: (1) To investigate the effects of ashpit effluent on the seasonal cycles of invertebrate fauna; (2) to investigate the effects and toxicity levels of the ashpit effluent on local invertebrate fauna, and (3) to monitor trace element levels in aquatic organisms upstream and downstream of the ash effluent (with the Trace Elements Subproject). Supporting data on effluent composition came from the Aquatic Chemistry and Trace Element subprojects.

In relation to Objective (1), two studies were conducted. The data collected in these studies are presented in data sets C10A1 and C10A2. Data set C10A1 (Changes in aquatic invertebrate communities near the Columbia Generating Station (1974-77)) presents the results of monthly (May through Oct.) sampling of aquatic invertebrates conducted over a period of 5-yr. Data set C10A2 (Effect of temperature on the life histories of five species of *ephemeroptera* near the Columbia Generating Station (1974-76)) presents records of head capsule widths of five species of *Ephemeroptera* (mayfly nymphs) collected in the aquatic system near the site.

In relation to Objective (2), three studies were conducted. The data collected in these studies are presented in data sets C10B1, C10B2, and C10B3. Data set C10B1 (Distribution of aquatic invertebrates colonizing artificial substrates upstream and downstream of the ash effluent of the Columbia Generating Station (1977)) presents the results of a survey made during summer 1977 of aquatic invertebrates colonizing modified Dendy samplers at nine stations upstream and downstream of the ash effluent and in streams adjacent to the power plant. Data set C10B2 (Short-term exposures of adult and young-of-year *Gammarus* to the ash effluent from the Columbia Generating Station (1978)) presents the results of two laboratory studies utilizing specimens of *Gammarus* from upstream Rocky Run and water samples from Rocky Run above the ash effluent and from the ashpit drain. These studies were designed to determine whether the young-of-year *Gammarus* were more sensitive to the ashpit effluent than the adults.

Data set C10B3 (Effects on *Asellus racovitzai* from exposure to food and water contaminated by ash effluent from the Columbia Generating Station (1977-78)) presents the results of a laboratory study utilizing specimens of *Asellus racovitzai* (an aquatic isopod) from the mint drain, water samples from the ashpit and mint drains, and leaves soaked at these two sites. This study was designed to determine the effect of water and food from the ashpit drain on *Asellus* growth and reproduction.

In relation to Objective (3), two studies were conducted. The data collected in these studies are presented in data sets C10C1 and C10C2. Data set C10C1 (Oxygen consumption of crayfish after caging at field sites, measured in site water and tap water, 1977) presents the results of a study designed to detect any changes in metabolic rate caused by exposure to coal-ash effluent. Data set C10C2 (Metal concentrations in muscle, exoskeleton and hepatopancreas of crayfish caged in field locations, 1978) presents the results of a study monitoring five metals to determine the effects of exposure to the ash effluent on metal concentrations in several types of crayfish tissues from specimens caged at sites near the Columbia Generating Station.

In addition to the five data sets described above, supplementary information concerning water quality at the different study sites is presented in data set C10D1. Data set C10D1 (Supporting water-quality data for aquatic stream-invertebrate studies (1974-78)) presents the results of water sampling at 15 sites upstream and downstream of the ash effluent to provide supporting data for the stream invertebrate studies.

The investigators included John Magnuson, Professor; Anne Forbes, Specialist; Judy Schwarzmeier, Research Assistant; and Dorothy Harrell, Graduate Student, all associated with the Limnology Laboratory at UW Madison. This report was compiled by Hilary McLellan, Data Analyst, Water Resources Center.

DATA SET C10A1: CHANGES IN AQUATIC INVERTEBRATE COMMUNITIES NEAR THE COLUMBIA GENERATING STATION

Data Summary

Investigators--

A. Forbes, J. Schwarzmeier, and J. Magnuson.

Abstract--

This data set contains identification and count records for insects and crustaceans sampled at five sites around the Columbia Generating Station from 1974 to 1977. Each site was sampled monthly from May through October during 2 or more years. These records were used to investigate the impact of the Columbia Generating Station on aquatic microinvertebrate communities. Assemblages of invertebrate species were compared in space and time by monitoring seasonal cycles of many organisms simultaneously.

Dates of Research--

1974 through 1977.

Data Form--

Computer file containing 877 units with three card-images/unit.

Data Format

Field Description--

Card #1

<u>Column</u>	<u>Format</u>	<u>Description</u>
1-20	3A6,A2	Species name
22-23	A2	Site; W1=Wisconsin River upstream, W2=Wisconsin River downstream, R1=Rocky Run upstream, R5=Rocky Run downstream, A6=ashpit drain
25-26	A2	Sample type BB=basket, L1=log, L2=log
28-29	I2	Month
30-31	I2	Day
32-33	I2	Year
35-38	I4	Species counts from sampler I
40-43	I4	Species counts from sampler II
45-48	I4	Species counts from sampler III
50-51	I2	Month
52-53	I2	Day
54-55	I2	Year
57-60	I4	Species counts from sampler I
62-65	I4	Species counts from sampler II
67-70	I4	Species counts from sampler III
80	I1	Card image number, 1 for #1

Cards #2 and #3

<u>Column</u>	<u>Format</u>	<u>Description</u>
22-23	A2	Site
25-26	A2	Sampling method
28-29	I2	Month
30-31	I2	Day
32-33	I2	Year
35-38	I4	Species counts from sampler I
40-43	I4	Species counts from sampler II
45-48	I4	Species counts from sampler III
50-51	I2	Month
52-53	I2	Day
54-55	I2	Year
57-60	I4	Species counts from sampler I
62-65	I4	Species counts from sampler II

I4 Species counts from sampler III
I1 Image card, image number

Missing Data--

Missing data are indicated by 9999.

Data Sample

The sample presented here is 5 records, 1 to 5 of the 877 records included in the complete data set C10A1.

	W1	BB	52474	0	0	0	62674	0	0	9999	
CRANGONYX SP.	W1	BB	73174	0	1	9999	83074	2	0	9999	1
	W1	BB	92774	0	0	8	102574	0	0	0	2
HYALELLA AZTECA	W1	BB	52474	1	0	1	62674	1	2	9999	3
	W1	BB	73174	0	0	9999	83074	0	0	9999	1
	W1	BB	92774	8	0	0	102574	2	4	0	2
ASELLUS RACOVITZAI	W1	BB	52474	0	1	4	62674	14	21	9999	3
	W1	BB	73174	0	1	9999	83074	2	1	9999	1
	W1	BB	92774	16	0	0	102574	0	12	0	2
ACRONEURIA SP.	W1	BB	52474	0	0	0	62674	2	0	9999	3
	W1	BB	73174	0	0	9999	83074	0	1	9999	1
	W1	BB	92774	0	0	0	102574	0	0	0	2
ISOPERLA SP.	W1	BB	52474	62	52	89	62674	0	0	9999	3
	W1	BB	73174	0	0	9999	83074	0	0	9999	1
	W1	BB	92774	0	0	0	102574	22	4	16	2

Quality Assurance

Objectives--

The purpose of the study was to investigate the impact of the Columbia Generating Station on aquatic microinvertebrates around the power plant. Assemblages of invertebrate species were compared in space and time by following seasonal cycles of many organisms simultaneously. The inclusion of two methods permitted a comparison between the type of aquatic invertebrates colonizing natural substrates and those colonizing artificial substrates. Samples were collected for 1 yr before and 3 yr after station operations began.

Sampling Sites--

Five sampling stations (W1, W2, R1, R5, R6) were selected, based on stream-flow patterns at the Columbia site, to represent environmental

conditions at increasing distances from the generating station. The location of these stations is shown in Figure 21. Station W1, located on the Wisconsin River 0.4 km upstream from the intake channel, was selected as a control site since it should not have been affected directly by discharge from the power plant. The combined effects of the power plant, on the biota in the Wisconsin River and Rocky Run Creek, were measured at station W2 located approximately 3 km downstream from the intake channel. Effects of the ashpit drain were monitored at stations R5 and A6. Station R5 was located near the mouth of Rocky Run Creek by the north bank, approximately 1.5 km downstream from the bridge on County HWY JV. Station A6 was located at the ashpit drain approximately 3-km south of the generating station. Station R1, located approximately 6 m upstream from the County HWY JV bridge on Rocky Run, served as a control for the two ashpit monitoring sites.

Experimental Method--

Two sampling methods were used--basket-type and log samplers. The basket-type artificial-substrate samplers were Model 2911 chicken baskets from Androck, Inc. (20x28cm hexagons of 1.3-cm mesh) or a homemade replica of 1/2" (1.2 cm) chicken wire. The baskets were filled with measured amounts of washed limestone, 4.5 kg of No. 3 size gravel (average diameter 7.5 cm). The gravel filled baskets were suspended from overhanging branches near the shore so that they hung 5 to 10 cm above the substrate. Changing current speeds and decreasing water levels throughout the seasons often made this distance impossible to maintain. There were three basket samplers per site and samples were collected once each month from May through October during each year of the study. Not all the sites were sampled in 1976 and 1977. To collect the samples, each basket was drawn carefully to the surface and shaken inside a D-frame aquatic net.

In 1976, the second sampling method--using log substrate samplers--was initiated at the Wisconsin River station. A log of silver maple (*Acer saccharine*) with an approximately uniform diameter (ranging from 13 to 17 inches) was taken from the Wisconsin River floodplain and cut into 6 sections each 21 cm wide. Each section was converted into a natural substrate sampler. A pair of 3 in. eyebolts were screwed into each log section at opposite ends and snap hooks were attached to these bolts. The log section was held suspended below the water from a hook. From the other hook, a lead weight of approximately 4.5 kg was attached to hang beneath the log section to hold it suspended vertically under the water. There were six log samplers, separated into two sets of three. The two sets of log samplers were placed in the Wisconsin River in the vicinity of sampling station W2. One set was situated approximately 15 m downstream from the other. Every 2 weeks, one set of samplers was emptied on an alternate basis; there are monthly records for each of the six samples. To collect samples, the logs were drawn to the surface inside a D-frame aquatic net and unhooked. Organisms were removed with brushes and forceps and the logs were rehooked and replaced in the water.

Samples collected from both basket and log samplers were placed in 70% alcohol in plastic bags and returned to the laboratory.

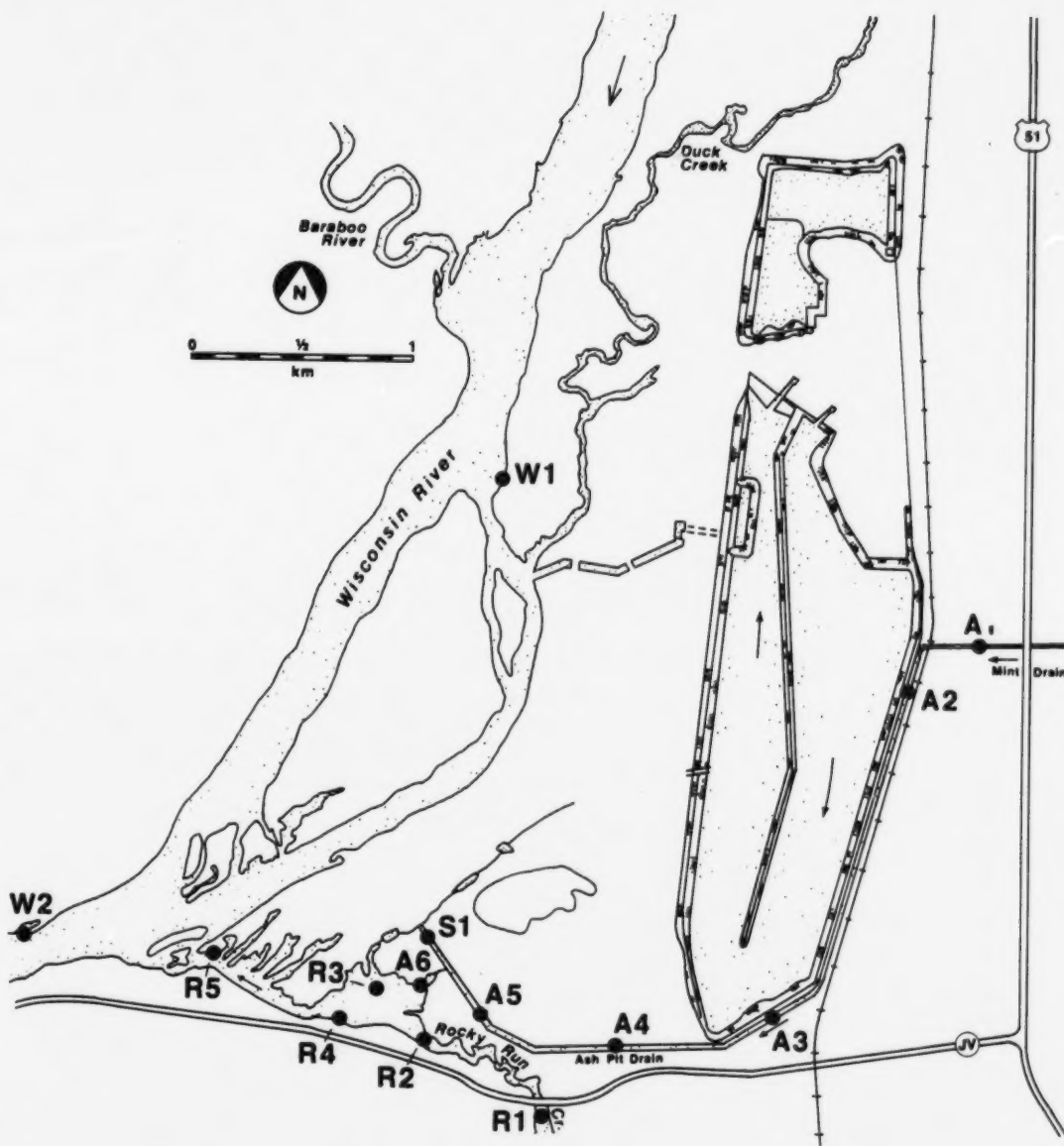


Figure 21. Aquatic invertebrate sampling stations near the Columbia Generating Station.

Analytical Procedure--

Insects and crustaceans were sorted, identified and counted in the laboratory. Each sample was split in quarters before sampling to make the sampling time more manageable. If more than 2.5 hr were required to sort the first quarter, this sample was further subdivided. Each subsample count was multiplied by four (or a greater number if the first quarter was further subdivided) to obtain an estimated count for the sample as a whole.

Identification in most cases was to the generic or family level; specific identifications were made where possible. Immature specimens of the Hydropsychidae and Corixidae could not be identified to genus; separate categories were created for them. Pupae were keyed to family.

Investigators--

All parts of this experiment were conducted by Anne Forbes and Judy Schwartzmeier. At the time of the experiment, Anne Forbes, who has an M.S. in Zoology from the University of Rhode Island, was working as a specialist in the Limnology Laboratory. Judy Schwartzmeier was working toward an M.S. in Limnology at the University of Wisconsin-Madison. The experiment was conducted at the Columbia site under the supervision of Professor John Magnuson of the Zoology Department. Field assistants with experience in limnology assisted in the data collection.

Supporting Documents

Aquatic invertebrates. In: Documentation of environmental change related to the Columbia Electric Generating Station. Institute for Environmental Studies, Reports 58, 62, 66, 69, 92, University of Wisconsin-Madison.

Magnuson, J.J., A.M. Forbes, D.M. Harrell, and J.D. Schwarzmeier. 1980. Responses of aquatic invertebrates to an ashpit effluent, U.S. Environmental Protection Agency, Cincinnati, Ohio.

DATA SET C10A2: EFFECT OF TEMPERATURE ON THE LIFE HISTORIES OF FIVE SPECIES OF EPHEMEROPTERA NEAR THE COLUMBIA GENERATING STATION (1974-76)

Data Summary

Investigators--

J. Schwarzmeier and J. Magnuson.

Abstract--

This data set contains records of head-capsule widths, according to size class, for five species of *Ephemeroptera* (mayfly nymphs) collected at the Wisconsin River and Rocky Run Creek in the preceding study (data set

C10A1). Head capsule widths of specimens of *Heptagenia flaviscens*, *Stenonema exigium*, *Stenonema terminatum*, *Stenacron interpunctatum*, and *Stenonema fuscom* were recorded on a monthly basis during May through October 1974-76.

Dates of Research--

1974-1976.

Data Form--

Computer file containing 115 units with one card-image/unit.

Data Format

Field Description--

Card #1

<u>Column</u>	<u>Format</u>	<u>Description</u>
1-2	I2	Species I.D.; 01= <i>Heptagenia flaviscens</i> , 02= <i>Stenonema exigium</i> , 03= <i>Stenonema terminatum</i> , 04= <i>Stenonema interpunctatum</i> , 05= <i>Stenonema fuscom</i>
4-5	A2	Location code; W1=upstream Wisconsin River, W2=downstream Wisconsin River, WB=both Wisconsin River stations, R1=Rocky Run upstream, R5=Rocky Run downstream, RB=both Rocky Run stations
7-8	A2	Sample type code; BB=artificial substrate (basket sampler), LL=natural substrate (log sampler), BL=both types combined
10-11	I2	Month
12-13	I2	Day
14-15	I2	Year
17-20	I4	Total count of species for date shown
22-24	I3	Specimen count in size class (0.01-0.25 head capsule width)
26-28	I3	Specimen count in size class (0.26-0.50 head capsule width)
30-32	I3	Specimen count in size class (0.51-0.75 head capsule width)
34-36	I3	Specimen count in size class (0.76-1.00 head capsule width)
38-40	I3	Specimen count in size class (1.01-1.25 head capsule width)
42-44	I3	Specimen count in size class (1.26-1.50 head capsule width)
46-48	I3	Specimen count in size class (1.51-1.75 head capsule width)
50-52	I3	Specimen count in size class (1.76-2.00 head capsule width)
80	I1	1 for image #1

Card #2

1-2	I2	Species identification number
4-5	A2	Location code
7-8	A2	Sampling method
10-11	I2	Month
12-13	I2	Day
14-15	I2	Year
17-20	I4	Total count for date
22-24	I3	Specimen count in size class (2.01-2.25 head capsule width)
26-28	I3	Specimen count in size class (2.26-2.50 head capsule width)
30-32	I3	Specimen count in size class (2.51-2.75 head capsule width)
34-36	I3	Specimen count in size class (2.76-3.00 head capsule width)
38-40	I3	Specimen count in size class (3.01-3.25 head capsule width)
42-44	I3	Specimen count in size class (3.26-3.50 head capsule width)
46-48	I3	Specimen count in size class (3.51-3.75 head capsule width)
50-52	I3	Specimen count in size class (3.76-4.00 head capsule width)
80	I1	2 for image #2

Missing Data--

Not applicable.

Data Sample

The sample presented here is 1 units, 1 to 10, of the 115 units included in the complete data set C10A2.

1234567890123456789012345678901234567890123456789012345678901234567890

01 WB BB 052474	316	0	0	0	2	6	20	28	40		
01 WB BB 052474	316	53	50	42	23	30	11	10	1		1
01 WB BB 062674	130	0	0	2	15	26	12	17	10		2
01 WB BB 062674	130	4	9	17	12	6	0	0	0		1
01 WB BB 073174	3	0	0	0	0	1	0	0	1		2
01 WB BB 062674	3	1	0	0	0	0	0	0	0		1
01 WB BB 083074	10	0	0	4	2	1	0	0	1		2
01 WB BB 083074	10	0	2	0	0	0	0	0	0		1
01 WB BB 092774	12	0	0	1	3	4	1	2	1		2
01 WB BB 092774	12	0	0	0	0	0	0	0	0		1
01 WB BB 102574	42	0	0	5	12	4	3	9	4		2
01 WB BB 102574	42	1	0	3	1	0	0	0	0		1
01 WB BB 061375	43	0	0	12	10	5	1	1	1		2
01 WB BB 061375	43	1	2	10	0	0	0	0	0		1
01 WB BB 070975	5	0	0	2	2	0	0	0	1		2
01 WB BB 070975	5	0	0	0	0	0	0	0	0		1
01 WB BB 080775	5	0	0	0	1	0	2	0	1		2
01 WB BB 080775	5	1	0	0	0	0	0	0	0		1
01 WB BB 090575	9	0	0	5	3	1	0	0	0		2
01 WB BB 090575	9	0	0	0	0	0	0	0	0		1
											2

Quality Assurance

Objectives--

The purpose of the study was to determine whether temperature is an influential factor in regulating mayfly life cycles. The life cycles of five species of *Ephemeroptera* (mayfly nymphs) were monitored by measuring the individual head-capsule widths. This group was chosen for life history analysis because it is abundant and easy to identify.

Sampling Sites--

The *Ephemeroptera* (mayfly nymph) specimens analyzed in this study were obtained at stations W1 and W2 on the Wisconsin River and stations R1 and R5 on Rocky Run Creek in the course of the study documented in data set C10A1.

Sampling Procedure--

Ephemeroptera specimens captured in the basket and log samplers described in data set C10A1 were used in this study.

Analytical Procedure--

Head-capsule widths of the *Ephemeroptera* were measured using a binocular microscope equipped with an ocular grid that was calibrated with a slide micrometer. The head width was chosen for measurement because the degree of contraction caused by alcohol is much less variable for the head capsule than for total length, giving greater reliability. The abundance of each species in each size class was recorded providing the basis for determining life history patterns--times of emergence, hatching, and growth.

Investigators--

All parts of the experiment were conducted by Judy Schwartzmeier, who at the time of the experiment was working toward an M.S. degree in Limnology at the University of Wisconsin-Madison. The experiment was conducted under the supervision of Professor John Magnuson of the Zoology Department.

Supporting Documents

Same as data set C10A1.

DATA SET C10B1: DISTRIBUTION OF AQUATIC INVERTEBRATES COLONIZING ARTIFICIAL SUBSTRATES UPSTREAM AND DOWNSTREAM OF THE ASH EFFLUENT OF THE COLUMBIA GENERATING STATION (1977)

Data Summary

Investigators--

A. Forbes and J. Magnuson.

Abstract--

This data set contains identification and count records for aquatic invertebrates colonizing artificial-substrate samplers placed at sites in the mint drain (upstream of the ash effluent), in the ashpit drain, and in Rocky Run Creek (both upstream and downstream of the ash effluent). These records were used to investigate the effect of the ash effluent on numbers of individuals and numbers of taxa.

Dates of Research--

June 1977 and September 1977.

Data Form--

Computer file containing 174 units with one card-image/unit.

Data Format

Field Description--

<u>Column</u>	<u>Format</u>	<u>Description</u>
1-20	3A6,A2	Genus name
22-23	A2	Site number (see Figure 21)
25-26	I2	Month
27-28	I2	Day
29-30	I2	Year
32	I1	Number of samplers used
34-36	I3	Count in first sampler

38-40	I3	Count in second sampler
42-44	I3	Count in third sampler
46-48	I3	Count in fourth sampler
50-52	I3	Count in fifth sampler
54-56	I3	Count in sixth sampler
58-60	I3	Count in seventh sampler

Missing Data--

Not applicable.

Data Sample

The sample presented here is 15 records, 1 to 15, of the 174 records included in the complete data set C10B1.

12345678901234567890123456789012345678901234567890

CRAGONYX	A1 060277 3	6	22	9
HYALELLA	A1 060277 3	795	266	534
ASELLUS	A1 060277 3	2	128	20
GAMMARUS	A1 060277 3	0	1	0
BAETIS	A1 060277 3	1	0	0
CENTROPTILIUM	A1 060277 3	1	0	0
CAENIS	A1 060277 3	2	2	6
COENAGRIONIDAE	A1 060277 3	1	0	1
PLEA	A1 060277 3	1	1	1
SIGARA	A1 060277 3	0	0	1
BEROSUS LARV.	A1 060277 3	1	0	0
DEIONECTES	A1 060277 3	1	0	1
DUBERAPHIA	A1 060277 3	1	0	0
LACCOPHILUS LARV.	A1 060277 3	4	1	5
PELTODYTES	A1 060277 3	1	1	1

Quality Assurance

Objective--

The purpose of the study was to determine the effect of the ash effluent on aquatic invertebrates downstream from the ashpit drain.

Sampling Sites--

The sampling sites varied on different sampling dates. On 2 June 1977, sampling was carried out at seven stations: A1, A2, A3, A6, R1, R2, and R3 (Figure 21). On 9 September 1977, sampling was carried out at seven stations, some different from the June sampling stations: A1, A2, A3, R2, R3, R4, and S1. Station A1 (an uncontaminated control site) is located in the mint farm drain, upstream of the ashpit drain. Stations A2 and A3 (contaminated sites) are located in the ashpit drain, west and south of the cooling lake. Station A6 (a contaminated site) is located at the point where one of the ashpit drain outlets joins Rocky Run Creek. Stations R1 and R2 are both uncontaminated control sites located upstream of the ashpit drain in Rocky Run Creek. Station R1 is located approximately 6 m upstream from the County HWY JV bridge on Rocky Run Creek. Station R2 is located

approximately 0.8 km downstream from the County HWY JV bridge and just above the slough where the ashpit drains into Rocky Run Creek. Station R3 (a contaminated site) is located in Rocky Run Creek by the north shore near one of the two outlets from the ashpit drain. Station R4 (a contaminated site) is located near the south shore of Rocky Run Creek across from the ashpit-drain outlets. Station S1 (a contaminated site) is located in the ashpit drain, between the two outlets where it empties into Rocky Run Creek.

Sampling Equipment and Procedures--

The invertebrate community was sampled with modified Dendy samplers. Each sampler was made from a single Tuffly-brand plastic-mesh ball held between two 8 x 8 cm masonite plates by an eyebolt and wing nut. Samplers were held in place with floats and weights. Since the modified Dendy samplers could be placed anywhere in the stream, they could be placed at sites closer to the ash effluent. In June, three samplers were placed at each of the seven sampling stations. In September, four samplers were placed at stations A1, A2, A3, A6, and S1; eight samplers were placed at stations R2, R3, and R4.

After a 1-week exposure, the samplers were removed and placed into freezer containers with 70% alcohol. The 1-week exposure time was selected to minimize the buildup of detritus around the sampler.

At the time of collection in September, a number of samplers were missing at several of the stations: R2, R3, R4, A5, and A6. It is suspected that these losses were due to sudden, extremely high ashpit-drain flow or removal by boaters.

In the laboratory, the organisms were identified and counted.

Investigators--

The experiment was conducted by Anne Forbes, who at the time of the experiment was working as a specialist in the Limnology Laboratory at the University of Wisconsin-Madison. She has an M.S. in Zoology from the University of Rhode Island. The experiment was conducted under the supervision of Professor John Magnuson.

Supporting Documents

Same as data set C10A1.

DATA SET C10B2: SHORT-TERM EXPOSURES OF ADULT AND YOUNG-OF-YEAR *GAMMARUS* TO THE ASH EFFLUENT FROM THE COLUMBIA GENERATING STATION (1978)

Data Summary

Investigators--

A. Forbes and J. Magnuson.

Abstract--

This data set contains records of the number of *Gammarus pseudolimnaeus* survivors from a group exposed to ash effluent from the Columbia Generating Station in two laboratory experiments. These experiments were designed to determine whether the young-of-the-year *Gammarus* were more sensitive to the ash effluent than the adults.

Dates of Research--

May through July 1978.

Data Form--

Computer file containing 9 units with one card-image/unit.

Data Format

Field Description.

<u>Column</u>	<u>Format</u>	<u>Description</u>
1	I1	Experiment
3-8	A6	Experimental condition
10	I1	Age; 1=adult, 2=young-of-year
12-14	I3	Percentage of ashpit-drain water used in tanks (%)
16-17	I2	Number of living Gammarus--Day 0
19-20	I2	Number of living Gammarus--Day 1
22-23	I2	Number of living Gammarus--Day 2
25-26	I2	Number of living Gammarus--Day 3
28-29	I2	Number of living Gammarus--Day 4
31-32	I2	Number of living Gammarus--Day 5 (Exp II only)
34-35	I2	Number of living Gammarus--Day 6 (Exp II only)
37-38	I2	Number of living Gammarus--Day 7 (Exp II only)
40-41	I2	Number of living Gammarus--Day 8 (Exp II only)
43-44	I2	Number of living Gammarus--Day 9 (Exp II only)

Missing Data-

Not applicable.

Data Sample

The sample presented here is the complete data set C10B2.

123456789012345678901234567890123456789012345

1	L1CONT	1	0	10	10	10	10	10	10										
1	L1APDR	1	100	10	10	7	7	7											
1	L1CONT	2	0	10	10	10	10	9											
1	L1APDR	2	100	10	7	5	3	2											
2	L2CONT	1	0	12	12	12	12	12	12	12	12	11	11	11					
2	L2	25	1	25	12	12	12	12	12	12	12	12	12	12	12				
2	L2	50	1	50	12	12	12	12	12	12	12	12	12	12	12				
2	L2	75	1	75	12	12	12	12	12	12	12	12	12	12	12				
2	L2	100	1	100	12	12	12	12	12	12	12	12	12	12	12				

QUALITY ASSURANCE

Objective--

The purpose of the study was to determine whether the young-of-the-year *Gammarus pseudolimnaeus* would be more sensitive than the adults to ash effluent.

Data Collection--

Specimens of *Gammarus* were collected from Rocky Run Creek above the ash effluent (site R1 in Figure 21).

Water samples were obtained in 5 gal polyethylene containers from the ashpit drain and Rocky Run Creek above the ash effluent, providing a series of dilutions of ash effluent in Rocky Run water so that a level of concentration could be selected.

Experimental Procedures and Equipment--

Experiment I: *Gammarus* were captured by hand net on 31 May 1978 and returned to the laboratory where they were placed individually in 40 beakers (500 ml) at 17°C. Aerators were added to the apparatus for this experiment. Twenty young-of-year (4.6 ± 0.6 mm body length) and 20 adult (9.8 ± 2.2 mm) amphipods were used. After 24-hr acclimation in Rocky Run water, the water was changed in all beakers with half the adults and half the young receiving ashpit water instead of Rocky Run (uncontaminated) water. Treatments were randomly assigned to the beakers. The beakers were checked daily for 4 days. Dead amphipods were removed and preserved in 90% alcohol.

Experiment II: Young-of-year *Gammarus* were collected from Rocky Run above the ash effluent on 28 June 1978 and placed individually in 60 beakers in the water bath at 17°C. After 24-hr acclimation in Rocky Run water, the water in all beakers was changed with groups of 12-randomly selected beakers receiving one of the following water types: (1) 100% Rocky Run, (2) 75% Rocky Run + 25% ashpit drain, (3) 50% Rocky Run + 50% ashpit drain, (4) 25% Rocky Run + 75% ashpit drain, (5) 100% ashpit drain. Beakers were checked daily for dead animals for 4 days. Water was changed once at 48 hr. Since no mortalities occurred the experiment was continued for 4 more days with a

water change at 48 hr. The experiment was terminated because heavy rains continued to dilute the effluent below its toxic level as determined in Experiment I.

Investigators--

Same as data set C10B1.

Supporting Documents

Same as data set C10A1.

DATA SET C10B3: EFFECTS ON *ASELLUS RACOVITZAI* FROM EXPOSURE TO FOOD AND WATER CONTAMINATED BY ASH EFFLUENT FROM THE COLUMBIA GENERATING STATION (1977-78)

Data Summary

Investigators--

A. Forbes and J. Magnuson.

Abstract--

This data set contains records of the numbers of *Asellus racovitzai* that survived under five laboratory conditions involving variations in food and water quality. This study was designed to determine the effect of water and food from the ashpit drain on *Asellus* (aquatic isopods).

Dates of Research--

December 1977-March 1978.

Data Form--

Computer file containing 29 units with one card-image/unit.

Data Format

Field Description--

<u>Column</u>	<u>Format</u>	<u>Description</u>
1-2	I2	Day number of experiment
4-5	I2	Number of living <i>Asellus</i> in treatment A
7-8	I2	Number of living <i>Asellus</i> in treatment B
10-11	I2	Number of living <i>Asellus</i> in treatment C
13-14	I2	Number of living <i>Asellus</i> in treatment D
16-17	I2	Number of living <i>Asellus</i> in treatment E

Missing Data--

No missing data.

Data Sample

The sample presented here is the complete data set C10B3.

12345678901234567890

1	70	70	70	70	70
2	70	70	70	70	70
4	70	70	70	70	70
8	70	70	70	70	70
11	70	68	70	68	70
16	69	68	68	68	68
18	69	67	68	68	64
22	69	66	67	68	58
25	66	64	67	68	54
29	66	63	67	68	50
32	66	63	67	67	49
36	66	61	66	67	47
39	65	60	66	66	43
43	65	59	66	64	42
46	65	59	60	64	41
50	65	59	59	63	41
53	65	59	57	62	41
57	61	59	56	60	41
60	60	58	56	60	39
64	57	56	53	59	35
67	53	56	51	58	35
71	51	51	48	55	31
74	50	43	44	54	27
78	46	41	42	53	24
81	41	37	39	50	23
85	35	30	37	46	17
88	30	29	32	39	15
91	25	22	24	30	9
92	21	20	21	28	9

Quality Assurance

Objectives--

The original purpose of this study was to determine if *Asellus* (aquatic isopods) exposed to contaminated water and food from the ashpit drain prior to the spring reproductive pulse would grow more slowly and produce fewer young than *Asellus* provided with uncontaminated food and water. The high mortality rate of *Asellus* exposed to contaminated water and food precluded the study of reproductive success.

Experimental Design--

Exposure to treatment water and leaf discs began on 20 Dec. 1977. The study was set up in terms of a 2 x 2 factorial design with an additional control group. The first factor was food with two categories--contaminated and uncontaminated. The second factor was water with two categories--contaminated and uncontaminated. The additional control group had uncontaminated food with filtered contaminated water. The water for the control category was ashpit water filtered (0.45 μ m) to remove particulates. Fourteen beakers were randomly assigned to each of the five categories.

Sampling Site--

Specimens of *Asellus racovitzai* were captured in the mint drain (site A1 in Figure 21), the site uncontaminated by effluent from the power plant. Water was collected in 5-gal containers at the uncontaminated mint drain site (A1) and the contaminated ashpit drain site (A4).

Experimental Procedure--

Specimens of *Asellus racovitzai* were captured by hand net. Leaves collected from a sugar maple and oven dried, were suspended in mesh packs to soak in water at either the contaminated site or the uncontaminated site for 2 weeks and finally cut into discs for use as food for *Asellus* in the laboratory. To soak them, individual leaves were placed in separate compartments in nylon bags. The bags were suspended with bricks and floats in the field at either site for 2 weeks. Placement of bags in the field was staggered so that a set soaked for 2 weeks was ready to be used each week. A 15-mm diameter stainless-steel cork borer was used to cut discs from the soaked leaves. Five specimens of mature *Asellus* (64 to 90 mm long, $\bar{x} = 80$ mm) were placed in each of 70 beakers.

The *Asellus* were checked daily and the dead specimens were counted and replaced with a living adult specimen.

The following procedure was repeated weekly. On the first day of each week, water and leaf bags from the two sites were collected. At the same time, new leaf bags were submerged at both sites to begin a 2-week exposure. During the second and fifth days of each week, the water and food discs in each beaker were changed, dead animals were removed, and the water removed from the beakers was analyzed (data set C10D1). Every day, the temperatures, pumps, etc. were checked.

The water bath was held at $3.81 \pm 0.23^{\circ}\text{C}$ and the soft-on, soft-off light controls were set at 9.5 hours light : 14.5 hours darkness. Temperature and photoperiod were accelerated weekly to simulate mid-April conditions by late February and therefore encourage earlier reproduction (Table 32).

Table 32. Temperature and photoperiod schedule for experimental procedure.

Dates	°C	Lights	
		On	Off
Dec. 20 - Jan. 29	3.81 ± 0.23	7:00	16:30
Jan. 30 - Feb. 5	5.92 ± 0.88	6:42	16:54
Feb. 6 - Feb. 12	7.75 ± 0.21	6:24	17:18
Feb. 13 - Feb. 19	10.01 ± 0.07	6:06	17:42
Feb. 20 - Feb. 26	11.82 ± 0.04	5:48	18:00
Feb. 27 - Mar. 21	13.92 ± 0.04	5:30	18:24

Investigators--

Same as data set C10B1.

Supporting Documents

Same as data set C10A1.

DATA SET C10B4: SUPPORTING WATER-QUALITY DATA FOR AQUATIC-STREAM
INVERTEBRATE STUDIES (1977-78)

Data Summary

Investigators--

A. Forbes, D. Harrell, J. Schwarzmeler, and J. Magnuson.

Abstract--

This data set contains the results of a water quality survey that was conducted to provide supporting data for the previous invertebrate studies. Samples were collected on an irregular basis at sites upstream and downstream of the ashpit effluent in the Wisconsin River and Rocky Run Creek, in the ashpit drain, and in the mint-farm drain. Samples were returned to the laboratory and analyzed for DO (mg/liter), conductivity (μ mhos/cm), alkalinity and hardness (mg/liter CaCO_3), and pH. Water temperature ($^{\circ}\text{C}$), current speed (cm/s), and turbidity (Jackson Turbidity Units) were measured in the field.

Dates of Research--

1974-1978.

Data Form--

Computer file containing 256 units with one card-image/unit.

Data Format

Field Description--

Column	Format	Description
1-2	I2	Month
3-4	I2	Day
5-6	I2	Year
8-13	A6	Site or experiment identifier
15-18	F4.1	Water temperature (°C)
20-23	F4.1	Current speed (cm/sec)
25-28	F4.1	Dissolved oxygen (mg/liter)
30-33	F4.1	Temperature of DO analysis (°C)
35-38	I4	Conductivity (mhos/cm) @ 25°C
40-44	F5.1	Phenolphthalein alkalinity
46-50	F5.1	Total alkalinity (mg/liter)CaCO ₃
52-56	F5.1	Hardness (mg/liter)
58-62	F5.2	pH
64-67	F4.1	Turbidity (JTU)

Missing Data--

Missing data are indicated by 999.

Data Sample

The sample presented here is 20 records, 237 to 256, of the 256 records included in the complete data set C10B4.

1234567890123456789012345678901234567890123456789012345678901234567890

080376	W2	23.5	29.7	8.9	999	219	0.	92.3	999	7.74	999
081876	W2	21.9	26.9	8.6	999	211	10.0	91.0	128.0	8.27	999
090176	W2	19.5	22.4	8.2	999	274	6.6	138.0	99.0	7.79	999
091476	W2	19.5	19.7	8.5	999	239	7.0	97.0	103.0	8.00	999
092876	W2	12.6	19.7	10.2	999	243	6.0	106.0	112.0	7.78	999
101276	W2	13.0	22.9	11.4	999	239	12.0	122.0	108.0	8.15	999
102676	W2	5.6	23.8	12.8	999	266	10.0	110.0	119.0	7.65	999
122377	ASELAB	3.8									
013078	ASELAB	5.9									
020678	ASELAB	7.8									
021378	ASELAB	10.0									
022078	ASELAB	11.8									
022778	ASELAB	14.0									
999999	L1CONT	17.7	999	999	999	559					
999999	L1APDR	17.7	999	999	999	1970					
999999	L2CONT	17.0	999	999	999	465	24.	256.	999	8.40	999
999999	L2	25	17.0	999	999	606	10.	220.	999	8.24	999
999999	L2	50	17.0	999	999	818	6.	106.	999	8.10	999
999999	L2	75	17.0	999	999	919	4.	146.	999	7.90	999
999999	L2	100	17.0	999	999	1111	0.	182.	999	7.70	999

Quality Assurance

Objectives--

The purpose underlying the study was to obtain chemical and physical water quality measurements at the field sites as supporting data for the invertebrate studies.

Sampling Sites--

Same as data set C10A1.

Sampling Equipment and Procedures--

Water samples were collected with a siphon apparatus (Magnuson and Stuntz 1970). Samples were obtained and returned to the laboratory for titration to determine DO, alkalinity, hardness, pH, and turbidity. Water temperature, conductivity, and current speed were measured in the field.

From 1974 to 1975 water temperatures were monitored with a direct-reading thermistor. Starting in 1976, a Yellow Springs Instrument Model 33 conductivity temperature meter was used to measure water temperature as well as conductivity. All conductivity readings are corrected to 25°C. Accuracy of measurement for both instruments was $\pm 0.1^\circ\text{C}$. The YSI Model 33 meter is calibrated by the manufacturer and designed to remain permanently calibrated.

Current speed, reported as an average of three readings, was measured with an Ocean equipment Model 451 meter from 1975 to 1976 and on a C.M. Neyrpic Midget Current Meter in 1977.

A Hach Model 2100A turbidity meter was used to measure turbidity (Jackson Turbidity units). Standards were run with every use.

Analytical Procedure--

Water samples were returned to the Limnology Laboratory, Univ. of Wisconsin-Madison for titration. The analytical techniques followed Standard Methods for the Examination of Water and Wastewater (American Public Health Association 1971).

Dissolved oxygen--A Yellow Spring Instrument Co. Model 54A meter was used to measure DO (mg/liter) except during 1976 when azide modification of the Winkler Method was used, as described in the American Public Health Association Standard Methods (1975). The YSI Meter was calibrated with every use.

Alkalinity--A Model Al-AP Hach kit was used before 1976 to measure alkalinity (mg/liter CaCO_3). Standards were run with every use. In 1976 and 1977, phenolphthalein and methyl orange indicators were used in accordance with the American Public Health Association Standard Methods (1971).

Hardness--EDTA titration was used to measure hardness according to American Public Health Association Standard Methods (1971). A fresh 7.4 buffer was used at all times.

pH--Before 1977 a Fisher Accumet Model 150 meter was used to measure pH. Standards were run with every use. Starting in 1977, a Hach model 17-H kit was used which showed phenol red pH.

Investigators--

The experiment was conducted by Anne Forbes, Dorothy Harrell, and Judy Schwartzmeier. At the time of the experiment, Anne Forbes, with an M.S. in Zoology from the University of Rhode Island, was working as a specialist in the Limnology Laboratory and Dorothy Harrell and Judy Schwartzmeier were both working toward M.S. degrees in Limnology at the University of Wisconsin-Madison. The study was conducted under the supervision of Professor John Magnuson.

Supporting Documents

Aquatic invertebrates. In: Documentation of environmental change related to the Columbia Electric Generating Station. Institute for Environmental Studies, Reports 69 and 92, University of Wisconsin-Madison.

Magnuson, J.J., A.M. Forbes, D.M. Harrell, and J.D. Schwarzmeier. 1980. Responses of aquatic invertebrates to an ashpit effluent. U.S. Environmental Protection Agency, Cincinnati, Ohio.

DATA SET C10C1: OXYGEN CONSUMPTION OF CRAYFISH IN TAP WATER AND IN WATER FROM THE COLUMBIA GENERATING STATION SITE (1977)

Data Summary

Investigators--

D. Harrell and J. Magnuson.

Abstract--

This data set contains records of O₂ consumption by crayfish in closed-system respirators after they had been caged in the field at the Columbia site. This study was designed to detect any changes in metabolic rate caused by exposure to coal-ash effluent from the Columbia Generating Station. Records are included for O₂ consumed (ml/hr) during two successive 24-hr experiments where the crayfish were subjected first to Columbia site water and then to tap water. In addition sex and wet weight (g) for each crayfish were recorded and the dates indicating the start and end of the period during which each crayfish was caged in the field.

Dates of Research--

16 September-25 November 1977.

Data Form--

Computer file containing 48 units with one card-image/unit.

Data Format

Field Description--

<u>Column</u>	<u>Format</u>	<u>Description</u>
1-3	A1	Site
5-6	I2	Crayfish identification number
7	I1	Sex; 1=male, 2=female
9-12	F4.2	Wet weight (g)
14-19	F6.4	Oxygen consumed in site water (mg/hr)
21-26	F6.4	Oxygen consumed in tap water (mg/hr)
28-31	I4	Date specimen caged in field (month, day)
33-36	I4	Date specimen released from cage (month, day)
38	I1	Final status of specimen; 0=specimen alive, 1=specimen died or escaped, hence no data

Data Sample

The sample presented here is 15 records, 1 to 15, of the 48 records included in the complete data set C10C1.

1234567890123456789012345678901234567890

A1	112	3.39	0.0755	0.0673	0913	1117	0
A1	121	4.21	0.111	0.0600	0920	1117	0
A1	212	4.15	0.107	0.0743	0913	1117	0
A1	221	6.89	0.142	0.0934	0913	1117	0
A1	312	2.96	0.110	0.0623	0927	1117	0
A1	321	7.61	0.118	0.0795	0927	1117	0
A1	411	8.56	0.191	0.147	0913	1117	0
A1	422	6.63	0.111	0.0603	0913	1117	0
A1	511	6.80	0.120	0.0799	0927	1117	0
A1	522	4.87	0.100	0.0823	0927	1117	0
A1	611	7.61	0.149	0.0659	0930	1117	0
A1	622	2.62	0.0593	0.0388	0930	1117	0
A4	111	6.88	0.0759	0.0567	0913	1117	0
A4	122	999	9999	9999	0913	1111	1
A4	211	4.73	0.0672	0.0535	0913	1117	0

Quality Assurance

Objectives--

The purpose of the study was to detect any changes in the metabolic rate of crayfish caused by exposure to coal ash effluent.

Sampling Sites--

Four sites were selected (Figure 21). Two were treatment sites--one located in the ashpit drain (A5) and one in Rocky Run Creek (R5--downstream of the confluence with the ashpit drain). Two control sites were located in the mint drain (A1) and in Rocky Run Creek (R1) upstream of the ash effluent.

Monitoring Equipment and Procedures--

Crayfish collected in June and Aug. 1977 throughout the area around the Columbia Generating Station were caged in plastic minnow traps, 6 traps/site, from 16 Sept. to 17 Nov. 1977. One male and one female crayfish occupied each cage, one animal in each compartment. The cages, resting on the substrate in the middle of each stream, were anchored perpendicular to the flow with bricks. The soft sediment at each site partially filled the cages. Organic matter and organisms in the sediment flowed into the cages, providing food for the crayfish. Cages were checked once or twice a week and animals missing or dead before 22 Oct. were replaced. The generating station shut down for maintenance from 3 Oct. to 19 Oct. 1977. During this interval, no ash effluent was pumped from the ashpit into the drainage system. Crayfish that survived the entire period were not exposed to fly ash effluent for 16 out of 62 days.

All surviving crayfish were returned to the laboratory on 17 Nov. and placed in closed-system respirometers in a controlled-temperature room. The crayfish were randomly assigned to locations in the experimental room in order to eliminate bias due to variation in light, etc., in different parts of the room. The crayfish were acclimated for 24 hr in water from their own caging sites that was continuously aerated. The water temperature was maintained at 5°C and the photoperiod was maintained at 10.5 hr light : 13.5 hr darkness, approximating November field conditions. After acclimation, the crayfish were subjected to two successive 24-hr exposures--first to water from the contaminated sites and then to tap water. During the exposure to water from the contaminated sites and the subsequent exposure to tap water, the water was aerated and filtered (0.45 μ Millipore filters) before use. At the start of both experiments, a water sample was siphoned from each respirometer into individual 30-ml reagent bottles, stoppered immediately, and analyzed for DO. The water removed for analyses was replaced with additional water under the assumption that the dissolved oxygen was identical. The stopper was inserted securely. At the end of both 24-hr exposures, another water sample was removed for analysis. Airstones were provided and animals remained undisturbed for the duration of the first and second exposures.

Temperatures in the experimental respirometers were measured by a mercury thermometer before and after both experiments. The mean temperature was 4.9°C $\pm$ 0.5°C with no difference between the two treatments. Twelve additional respirometers were maintained with either site or tap water, but containing no crayfish. These additional respirometers served as controls to determine DO changes not caused by crayfish. Triplicate DO

determinations from each of 7 experimental respirometers showed analytical error to be < 0.13 mg/liter O₂.

The samples of filtered (0.45 µm Millipore filters) water obtained at the start and end of both experiments were analyzed for conductivity, pH, hardness, and alkalinity. The results are contained in data set C10B4.

At the end of the second exposure (to tap water), each crayfish was weighed, measured (carapace length and maximum width), and frozen in a plastic bag.

Investigators--

The experiment was conducted by Dorothy Harrell who, at the time of the experiment, was working toward an M.S. degree in Limnology at the University of Wisconsin-Madison. The study was conducted under the supervision of Professor John Magnuson.

Supporting Documents

Same as data set C10B4.

DATA SET C10C2: METAL CONCENTRATIONS IN MUSCLE, EXOSKELETON, AND HEPATOPANCREAS OF CRAYFISH CAGED IN FIELD LOCATIONS NEAR THE COLUMBIA GENERATING STATION (1978)

Data Summary

Investigators--

D. Harrell and J. Magnuson.

Abstract--

This data set contains records of metal concentrations in the muscle, exoskeleton, and hepatopancreas tissues of the crayfish used in the study described in data set C10C1. This study was designed to determine the effects of exposure to the ash effluent on metal concentrations in several crayfish tissues. Five elements, Ba, Cr, Se, Zn, and Fe (ppm) were monitored.

Dates of Research--

1977-1978.

Data Form--

Computer file containing 48 units with four card-images/unit.

Data Format

Field Description--

<u>Column</u>	<u>Format</u>	<u>Description</u>
<u>Card #1</u>		
1-3	A3	Site
5-6	I2	Crayfish identification number
7	I1	Sex; 1=male, 2=female
9	I1	Organ analyzed 3=hepatopancreas
11-18	F8.4	Ba (peak energy 496 KeV) concentration (ppm)
20-24	F5.1	Standard deviation percentage error of Ba concentration ¹³
26-33	F8.4	Cr (peak energy 320 KeV) concentration (ppm)
35-39	F5.1	Standard deviation percentage error of Cr concentration
41-47	F8.4	Fe (peak energy 1099 KeV) concentration (ppm)
50-54	F5.1	Standard deviation percentage error of Fe concentration
56-63	F8.4	Fe (peak energy 1292 KeV) concentration (ppm)
65-69	F5.1	Standard deviation percentage error of Fe concentration
80	I1	Card image
<u>Card #2</u>		
1-3	A3	Site
5-6	I2	Crayfish identification number
7	I1	Sex; 1=male, 2=female
9	I1	Organ analyzed 3=hepatopancreas
11-18	F8.4	Se (peak energy 265 KeV) concentration (ppm)
20-24	F5.1	Standard deviation percentage error of Se concentration
26-33	F8.4	Se (peak energy 280 KeV) concentration (ppm)
35-39	F5.1	Standard deviation percentage error of Se concentration
41-47	F8.4	Zn (peak energy 1116 KeV) concentration (ppm)
50-54	F5.1	Standard deviation percentage error of Zn concentration
80	I1	Card image
<u>Card #3</u>		
1-3	A3	Site
5-6	I2	Crayfish identification number
7	I1	Crayfish sex; 1=male, 2=female

¹³Percent error is ± 1 standard deviation expressed as a percentage.

9	I1	Organ analyzed 1=muscle
11	I1	Indicator code for Ba ¹⁴
13-19	F7.3	Ba concentration (ppm)
21	I1	Indicator code for Cr
23-29	F7.5	Cr concentration (ppm)
31	I1	Indicator code for Fe
33-39	F7.3	Fe concentration (ppm)
41	I1	Indicator code for Se
43-49	F7.5	Se concentration (ppm)
51	I1	Indicator code for Zn
53-59	F7.3	Zn concentration (ppm)
80	I1	Card image

Card #4

1-3	A3	Site
5-6	I2	Crayfish identification number
9	I1	Organ analyzed 2=exoskeleton
11	I1	Indicator code for Ba
13-19	F7.3	Ba concentration (ppm)
21	I1	Indicator code for Cr
23-29	F7.5	Cr concentration (ppm)
31	I1	Indicator code for Fe
33-39	F7.3	Fe concentration (ppm)
41	I1	Indicator code for Se
43-49	F7.5	Se concentration (ppm)
51	I1	Indicator code for Zn
53-59	F7.3	Zn concentration (ppm)
80	I1	Card image

Missing Data--

999 indicates that the sample organism died or escaped before analysis. 998 indicates the lack of a well defined peak energy during irradiation.

¹⁴In the indicator code 0 indicates that the following entry is the exact measured value, and 1 indicates that the exact value is less than the following entry.

Data Sample

The sample presented here is 4 units, 1 through 4, of the 45 units included in data set C10C2.

1234567890123456789012345678901234567890123456789012345678901234567890

A1	112	3	12.87	210.	1.278	79.6	55.22	101.	152.2	41.3	1		
A1	112	3	3.317	24.4	3.087	37.9	68.23	6.7			2		
A1	112	1	24.15	1	0.4060	1	36.36	1	0.05743	0	89.46	3	
A1	112	2	11.89	1	0.5880	1	26.42	1	0.03097	1	2.818	4	
A1	121	3	32.13	69.6	7.272	11.6	256.9	16.1	311.4	15.4		1	
A1	121	3	2.912	22.5	3.599	42.7	140.2	3.4				2	
A1	121	1	42.66	0	1.930	1	115.0	1	0.08310	0	676.4	3	
A1	121	2	0	127.1	1	0.9023	0	1739.	1	0.09071	0	469.8	4
A1	212	3	10.25	134.	0.8223	63.2	67.34	32.4	26.86	96.2		1	
A1	212	3	2.574	15.6	2.690	36.4	72.99	3.9				2	
A1	212	1	41.22	1	0.8863	1	82.44	1	0.07801	0	67.52	3	
A1	212	2	0	220.3	1	1.550	0	915.9	1	0.1324	1	6.853	4
A1	221	3	18.82	79.5	7.023	9.9	651.0	5.1	602.3	6.1		1	
A1	221	3	4.684	8.6	6.611	14.1	131.1	2.5				2	
A1	221	1	29.29	1	0.8837	1	94.59	1	0.07357	0	651.3	3	
A1	221	2	0	131.1	0	3.033	0	1509.	0	0.06706	0	326.3	4

Quality Assurance

Objectives--

The purpose of the study was to determine the effect of the ash effluent on different types of crayfish tissues.

Sampling Sites--

Same as data set C10A3.

Experimental Procedures and Equipment--

The field caging is described in data set C10C1. In the laboratory, crayfish were dissected under a laminar-flow hood using separate stainless-steel tools for each tissue removed. Due to the relatively high amounts of Cr in chrome-plated stainless steel, scissors and scalpels were used as little as possible to avoid metal-on-metal abrasion which might contaminate the samples. Instruments were carefully cleaned after each dissection by washing with "Micro" brand detergent and rinsing with a series of solutions--distilled water, distilled-deionized water, methanol, and distilled-deionized water. Exoskeleton, gill tissue (not analyzed), hepatopancreas, and abdominal muscle were removed and placed in separate preweighed 0.71-g polyethylene vials, reweighed to obtain wet-tissue weights, and oven dried at 40°C--until two successive weighings indicated no further weight loss--to obtain dry weights. Carcasses were placed in preweighed 30-ml jars and also oven dried. Carcass dry weight and the four tissue dry weights were summed to obtain an approximate whole animal dry weight. Metal concentrations in exoskeleton and abdominal muscle were determined by the University of Wisconsin Nuclear Reactor using neutron activation. The neutron flux was 17×10^{12} neutron/cm²/sec. The metal concentrations obtained for the

standards inserted with the samples analyzed by the University of Wisconsin Nuclear Reactor Laboratory are presented in Table 33, along with the actual concentrations in the substances as determined by various sources.

The hepatopancreas samples were too small to be analyzed by the Nuclear Reactor without additional preparation. After drying, each hepatopancreas was transferred to preweighted, high purity quartz tubes (1.5 μ m inner diameter), reweighed, and heat sealed. Three types of standards were prepared and placed in the same size preweighed high purity quartz tubes. The standards were: (1) synthetic liquid standard containing 40.0 μ g/ml Cr and 60.0 μ g/ml Se in 0.4 HNO_3 ; (2) National Bureau of Standards--Standard Reference Material # 1471--orchard leaves; and (3) Canadian Certified Reference Materials Project SO4--Bottle 289 (described by Koons and Helmke 1978). The hepatopancreas samples and standards were irradiated at the Nuclear Reactor with a neutron flux of 8 to 10 $\times 10^{12}$ n/cm²/sec and allowed to "cool" for approximately 2 weeks. The quartz tubes were taped to the centers of posterboard cards to permit replication of sample geometry and each was radioassayed using high resolution gamma ray spectroscopy. Two Ge (Li) detectors, each having a nominal volume of 50 cm³ and a resolution for the ⁶⁰Co 1332 KeV line of 2.0 KeV (FWHM) were used for this work. The signals from each detector were routed through the appropriate amplifiers and analog to digital converters to a Traco Northern Model TN-11 computer based multichannel analyzer (Koons and Helmke 1978).

Where metal concentrations were high enough, peak areas were automatically calculated by the computer, with background and decay accounted for. In other cases, peak areas were calculated by assaying the tissue sample for a known time and comparing the peak size to the peak of a standard solution of known Cr-51 concentration. The amount of Cr-51 in the tissue sample was determined with appropriate corrections for radioactive decay.

Although data on a large number of elements were obtained by both methods, only five were studied--Ba, Cr, Se, Zn, and Fe.

These were selected because they had elevated concentrations in the ash effluent (Helmke, et al. 1976). Where two energy peaks were obtained for the same metal, a mean concentration was calculated. Interference caused discrepancies in some samples; such data were discarded.

It should be noted that only muscle, exoskeleton, and leaf material standards were analyzed by the Reactor. The hepatopancreas samples and the two standards other than leaf material were analyzed using facilities at the Soil Science Department. Because each value is based on only one sample rather than being a mean of several, no attempt was made to correct the crayfish tissue values in any way. Performing a correction based on only one sample could result in even greater inaccuracy. This correction--applied equally to all crayfish--would also make no difference in the statistical comparisons between groups. Because the tissue elemental concentrations agree fairly well with those presented by Schoenfield (1978) it is unlikely that deficiencies in the Reactor data seriously distort the true values.

TABLE 33. ELEMENTAL CONCENTRATIONS IN STANDARDS ANALYZED BY THE UNIVERSITY OF WISCONSIN
NUCLEAR REACTOR WITH THE REPORTED ACTUAL CONCENTRATIONS OF THE STANDARDS^a

Sample	Metal concentration (ppm)					
	Ba	Cr	Fe	Se	Zn	
SO-4 standard	Reactor Koons and Helmke (1978)	875.5±48.3 722.±1.9	46.71±0.98 75±5.2	16,740±182 23,500±1.3	---	317.3±11.8 93±2.7
Orchard leaves standard	Reactor NBS ^b	---	3.008±0.346 2.3	---	<0.03 0.08	---
Liquid standard ^c	Reactor Actual ^c	49.34±2.58 60.0	27.84±0.19 40.0	---	0.363±0.009 5.0	---

^aStandard deviations are reported for the values obtained by the Reactor Laboratory and for the actual concentrations. --- = no value reported for actual value of standard.

^bU.S. National Bureau of Standards.

^cPrepared from solutions of known concentrations.

Investigators--

Same as data set C10C1.

Supporting Documents

Same as data set C10B4.

REFERENCES

- American Public Health Association, American Water Works Association, Water Pollution Control Federation. 1975. Standard methods for the examination of water and wastewater. Washington, D.C. 890 p.
- Helmke, P.A., and Glenn Hanson. Trace elements. In: Documentation of Environmental change related to the Columbia Electric Generating Station. Institute for Environmental Studies, University of Wisconsin-Madison.
- Koons, R.D., and P.H. Helmke. 1978. Multielement activation analysis of CCRMP standard soils SO-1, SO-2, SO-3, and SO-4. Soil Sci. Soc. Am. J.
- Magnuson, J.J., and W.E. Stuntz. 1970. A siphon water sampler for use under the ice. Limnol. Oceanogr. 15:156-158.
- Schoenfield, M.B. 1978. Trace elements in aquatic organisms from the environment of a coal burning generating station. M.S. Thesis, University of Wisconsin. 226 p.

SECTION 11

FISH

The Fish Subproject was a combination of field and laboratory studies designed to allow evaluation of some important short- and long-term effects of the Columbia Electric Generating Station on fish. This report documents the data collected as a result of the field studies.

The principal goal of these field studies was to examine the impact of the construction and operation of the Columbia Electric Generating Station on the ecology and distribution of fish.

Specific objectives were: (1) To assess the spawning success of fish in marshes and streams near the Columbia Generating Station site; and (2) to determine whether unusually-warm-water temperatures existed that could stimulate early fish-egg development and fry emigration from the marsh before other environmental conditions were optimal.

In relation to objective (1), three studies were conducted. The data collected in these studies are presented in data sets C11A1, C11A2, and C11A3. Data set C11A1 (Spring-fish sampling at the Columbia Generating Station site (1976-78)) contains the results of a survey carried out at five stations near the Columbia Generating Station during three consecutive spawning seasons. Data set C11A2 (Northern pike egg and fry survival at the Columbia Generating Station site (1977)) contains length records for northern pike fry captured at four sites in the survey described in data set C11A1. Data set C11A3 (Northern pike egg and fry survival at the Columbia Generating Station site (1977)) presents survival records for northern pike eggs and fry placed in containers to incubate at three sites near the Columbia Generating Station.

In relation to objective (2), one study was conducted. The resulting data are presented in data set C11B1. Data set C11B1 (Water-temperature monitoring at the five fish-monitoring stations at the Columbia Generating Station site (1977)) presents records of water temperature measurements at five stations in Rocky Run Creek, the ashpit drain, and the mint-farm drain.

The investigators were James J. Magnuson, Professor; Mike Talbot, research Assistant; Frank Rahel, Research Assistant, and Patricia Medvick, Research Assistant; Department of Zoology, University of Wisconsin-Madison. The report was compiled by Hilary McLellan, Data Analyst, Water Resources Center.

DATA SET C11A1: SPRING-FISH SAMPLING AT THE COLUMBIA GENERATING STATION
SITE (1976-78)

Data Summary

Investigators--

Mike Talbot and John Magnuson.

Abstract--

This data set contains the results of a 3-yr survey carried out to examine the impact of the construction and operation of the station on the ecology and distribution of fish. These data include catch records by species, for 33 fish species.

Dates of Research--

March 1976 through April 1978.

Data Form--

Computer file containing 278 units with one card-image/unit.

Data Format

Field Description--

<u>Column</u>	<u>Format</u>	<u>Description</u>
1-5	I6	Date
8-9	I2	Net number
11-14	F4.1	Water temperature (°C)
16-18	I3	Number of different species captured in net. Indicates number of species counts on this image. 0--Net empty, 999--Net not set
20-21	I2	Species identification number ¹⁵
23-24	I2	Number of preceding species captured 20-24 repeated as needed up to 10 readings
26-27	I2)	2
29-30	I2)	
32-33	I2)	3
35-36	I2)	
38-39	I2)	4
41-42	I2)	
44-45	I2)	5
47-48	I2)	

¹⁵See Table 34.

TABLE 34. SPECIES LIST

Code number	Common name	Scientific name
01	Rock bass	<i>Ambloplites rupestris</i>
02	Bowfin	<i>Amia calva</i>
03	Pirate perch	<i>Aphredoderus sayanus</i>
04	Sheepshead	<i>Aplodinotus grunniens</i>
05	White sucker	<i>Catostomus commersoni</i>
06	Carp	<i>Cyprinus carpio</i>
07	Northern pike	<i>Esox lucius</i>
08	Muskellunge	<i>Esox masquinongy</i>
09	Black bullhead	<i>Ictalurus melas</i>
10	Yellow bullhead	<i>Ictalurus natalis</i>
11	Buffalo	<i>Ictiobus cyprinellus</i>
12	Pumpkinseed	<i>Lepomis gibbosus</i>
13	Bluegill	<i>Lepomis macrochirus</i>
14	Largemouth bass	<i>Micropterus salmoides</i>
15	Spotted sucker	<i>Minytrema melanops</i>
16	Redhorse	<i>Moxostoma</i> sp.
17	Yellow perch	<i>Perca flavescens</i>
18	White crappie	<i>Pomoxis annularis</i>
19	Black crappie	<i>Pomoxis nigromaculatus</i>
20	Rainbow trout	<i>Salmo gairdneri</i>
21	Walleye	<i>Stizostedion vitreum</i>
22	Mudminnow	<i>Umbra limi</i>
23	Golden shiner	<i>Notemigonus chrysolenca</i>
24	White bass	<i>Morone chrysops</i>
25	Blacknose dace	<i>Rhinichthys atratulus</i>
26	Brown bullhead	<i>Ictalurus nebulosus</i>
27	Sucker	<i>Catostomus</i> sp.
28	Chestnut lamprey	<i>Icthyomyzon castaneus</i>
29	Sauger	<i>Stizostedion canadense</i>
30	Smallmouth bass	<i>Micropterus dolomieu</i>
31	Brown trout	<i>Salmo trutta</i>
32	Sculpin	<i>Cottus</i> sp.

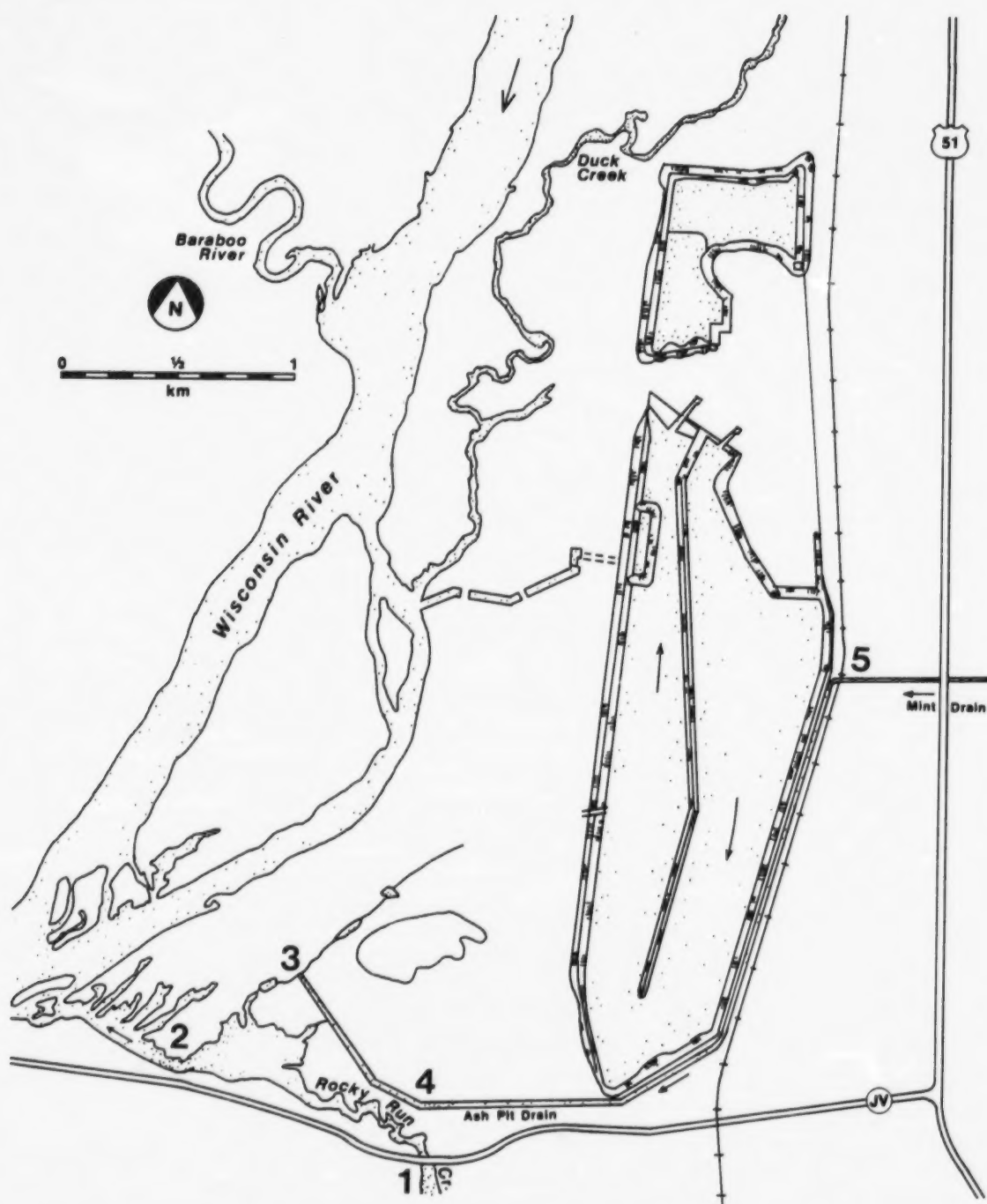


Figure 22. Location of fyke nets in spawning marshes on the Columbia site.

by-passed the station site. Water depths ranged from 1.5 to 3 m, depending on flood stage, and current was generally moderate. Spawning habitat was available immediately upstream when the creeks flooded surrounding marshland.

Site 2 was located in Rocky Run Creek downstream of its confluence with the ashpit drain. The net was placed in a channel between two old bridge abutments and except during peak flood periods, it captured all fish entering the marsh system. Water depth ranged from 1.5 to 3 m depending on flood stage and a strong current was always present. Spawning habitat was available immediately downstream of the net in a series of flooded sloughs. By the time it reached this station, the ash effluent was well mixed and greatly diluted.

Site 3 is located near the northern shore of the Rocky Run Creek backwaters and in the main current channel leading into the sedge meadow adjacent to the cooling lake. The net at this site caught fish that migrated into wetlands beyond those influenced by the ash effluent. Passage around the net was often possible when the entire area flooded, usually water levels dropped sharply at this site after the spring floods. Spawning habitat was present near the net but was mainly located upstream in flooded sedge meadows.

Site 4 was located in the ashpit drain above its junction with Rocky Run Creek. The net at this site caught fish entering spawning areas most heavily influenced by the ash effluent. The net was in a diked channel and caught most fish migrating upstream. The current was moderate to low and water levels were generally 0.5 to 2 m. Unlike site 3, this site retained a flow of water throughout the year. Abundant spawning habitat was available below and above this net. Amorphous clumps of an unknown precipitate that presumably originated in the ashpit effluent were often found floating downstream.

Site 5 was located above the confluence of the mint and ash drains. This net was used to determine if fish would migrate all the way up the ashpit drain to reach spawning grounds unaffected by the ash effluent. This site completely sealed off a small channel that was usually < 1 m deep but contained water throughout the year.

Sampling Procedure and Equipment--

Fyke nets were placed at each of the sites to capture adult fish migrating into the marsh to spawn. All field workers were versed in the identity of the different species of fish inhabiting the area around the Columbia Generating Station. Whenever doubts arose about the identity of a fish, some scale samples were taken from it and examined at the Limnology Laboratory of the University of Wisconsin-Madison by an expert and the identity was established. After the fish were identified they were tagged and released so that spawning migrations could be completed.

During 1976-77 electroshocking gear was also utilized to capture fish near the nets at sites 1 and 2. In contrast to the netting technique, this provided a mobile means to reach areas near the nets where the experimenters thought the fish would spawn. The electroshocking technique was used primarily to determine if a large number of fish were avoiding the nets but still utilizing the site for spawning. It was found that the fyke nets were a sufficient means of capturing fish and therefore no electroshocking was done in 1978.

As mentioned above, captured fish were tagged and released. The tag was inserted in the subopercular bone and carries an identification number as well as the label "University of Wisconsin-Madison." To determine the distribution of fish in the non-spawning season, notices were posted at each landing and fishing area offering rewards for returned tags obtained from fish caught.

Failure to recapture any tagged fish precluded any estimation of the 1976 population. Although logistics were improved through support from the Wisconsin Department of Natural Resources (WDNR), preliminary analysis of information gathered to date suggest continued difficulties in arriving at a reliable estimate of population size. Fyke net catch totals were low, and few tagged fish were recaptured. The Wisconsin River did not flood during the spring runoff period in 1977 and low water levels in the marsh hampered efforts to recapture fish on the spawning grounds. Low water levels may have contributed to a poor spawning run and low catches.

Investigators--

The experiment was conducted by Mike Talbot who at the time of the experiment was working toward a Ph.D. degree in Zoology at the University of Wisconsin-Madison. The experiment was conducted at the Columbia site under the supervision of Professor John Magnuson.

Supporting Documents

Aquatic invertebrates and fish. In: Documentation of environmental change related to the Columbia Electric Generating Station. Institute for Environmental Studies, Report 62, University of Wisconsin-Madison. p. 28-32.

Fish. In: Documentation of environmental change related to the Columbia Electric Generating Station. Institute for Environmental Studies, Reports 66, 69, 82, and 92, University of Wisconsin-Madison.

DATA SET C11A2: NORTHERN PIKE FRY SAMPLING AT THE COLUMBIA GENERATING STATION SITE (1976)

Data Summary

Investigators--

Mike Talbot and John Magnuson.

Abstract--

This data set contains records of northern pike fry captured at four sites in the 1976 fyke-net survey (data set C11A1). Individual lengths (in mm) of captured fry are recorded. These data were used to assess the spawning success of northern pike near the Columbia Generating Station.

Dates of Research--

5 to 24 May 1976.

Data Form--

Computer file containing 27 units with one card-image/unit.

Data Format

Field Description--

<u>Column</u>	<u>Format</u>	<u>Description</u>
1	I1	Month
2-3	I2	Day
4-5	I2	Year
7	I1	Site number
9	I1	Number of northern pike fry caught at this site
11-12	I2)	
14-15	I2)	
17-18	I2)	Individual lengths in mm of captured fry
20-21	I2)	Fields used as needed
23-24	I2)	
26-27	I2)	
29-30	I2)	

Missing Data--

No missing data.

Data Sample

The sample presented here is 27 records, the complete data set C11A2.

123456789012345678901234567890

```
50576 2 2 32 30
50576 3 0
50576 4 0
50776 2 0
50776 3 0
50776 4 1 27
51076 2 0
51076 3 0
51076 4 1 42
51276 2 0
51276 3 0
51276 4 2 30 47
51476 2 1 34
51476 3 3 25 27 28
51476 4 7 30 33 35 35 44 46 47
51776 2 1 48
51776 3 2 35 35
51776 4 0
51976 2 4 50 60 70 72
51976 3 1 35
51976 4 0
52176 2 2 60 70
52176 3 0
52176 4 0
52476 2 1 31
52476 3 2 43 43
52476 4 1 38
```

Quality Assurance

Objectives--

The purpose of the study was to determine relative fry abundance and egg deposition sites for northern pike. The experimenters believed that by studying these data they would be able to determine if successful reproduction had occurred in areas receiving the ash effluent from the Columbia Generating Station.

Sampling Site--

Minnow traps were placed at four sites, stations 1, 2, 3, and 4 (Figure 22). Two traps were set at each of the three sites where nets 2, 3, and 4 were located. Only one trap was set at the fourth location, near net 1. Refer to data set C11A1 for a description of the sites.

Sampling Equipment--

Minnow traps (2/3 x 2/3 x 1 m) were used to monitor the period of egg hatching and relative abundance of fry. The traps were set in midchannel. They were checked, emptied, and reset daily during the study period.

The traps were set during 1976 and 1977 but no northern pike fry were caught during 1977.

The length gain for the northern pike fry at the Columbia Generating Station site was compared to length gains reported for fry at two other sites, Gilbert Lake, Wisconsin (Priegel and Krohn 1975) and Lake George (Franklin and Smith 1963). However, small sample size precluded any comparisons of growth rates or estimates of fry abundance between sampled areas. After consultation with experts in fish egg collection (G. Priegel: personal communication, spring 1976), it was decided that estimations of total egg production, degree of egg deposition, and resulting fry survival should be made from literature sources currently available (Carbine 1944, Kysling and Frost 1969, Franklin and Smith 1963, Priegel and Krohn 1975, Kleinert 1970).

Supporting Documents

Same as data set C11A1.

DATA SET C11A3: NORTHERN PIKE EGG AND FRY SURVIVAL AT THE COLUMBIA GENERATING STATION SITE (1977)

Data Summary

Investigators--

Mike Talbot and John Magnuson.

Abstract--

This data set contains survival records for northern pike eggs and fry placed in containers to incubate at three sites near the Columbia Generating Station. These data were used to determine the effect of the ash effluent on northern pike spawning success in the river system adjacent to the Columbia site.

Dates of Research--

16 through 26 April 1977.

Data Form--

Computer file containing 90 units with one card-image/unit.

Data Format

Field Description--

<u>Column</u>	<u>Format</u>	<u>Description</u>
1	I1	Site
3	I1	Stage, 0=egg, 1=fry
5-6	I2	Bottle number
8-10	I3	Number living 4/16/77
12-14	I3	Number surviving 4/17/77
16-18	I3	Number surviving 4/18/77
20-22	I3	Number surviving 4/19/77
24-26	I3	Number surviving 4/20/77
28-30	I3	Number surviving 4/21/77
32-34	I3	Number surviving 4/22/77
36-38	I3	Number surviving 4/23/77
40-42	I3	Number surviving 4/24/77
44-46	I3	Number surviving 4/25/77
48-50	I3	Number surviving 4/26/77

Missing Data--

Missing data are indicated by 999.

Data Sample

The sample presented here is 15 records, 50 to 65, of the 90 records included in data set C11A3.

```
1234567890123456789012345678901234567890
2 0 16 187 167 1 0 0 0 0 0 0 0
2 1 16 0 0 40 34 34 34 32 32 32 32
2 0 17 201 192 4 0 0 0 0 0 0 0
2 1 17 0 1 28 27 22 22 999 999 999 20
2 0 18 195 187 0 0 0 0 0 0 0 0
2 1 18 0 0 8 6 6 6 999 999 999 5
2 0 19 185 185 19 0 0 0 0 0 0 0
2 1 19 0 0 20 12 11 10 999 999 999 6
2 0 20 201 200 3 0 0 0 0 0 0 0
2 1 20 0 0 2 2 2 1 1 1 1 1
4 1 01 50 999 49 47 46 39 999 999 999 30
4 1 02 50 50 50 50 49 49 999 999 999 30
4 1 03 50 50 50 50 50 49 999 999 999 30
4 1 04 50 50 50 47 47 47 999 999 999 29
4 1 05 50 999 47 45 43 2 2 2 2 2
```

Quality Assurance

Objectives--

The purpose of this study was to determine the effect of the ash effluent from the Columbia Generating Station on northern pike egg and fry survival.

Monitoring Sites--

Incubator containers for northern pike eggs and fry were placed at three sites 1, 2, and 4 (Figure 22). These sites are described in data set C11A1.

Monitoring Procedure--

Refer to experimental method.

Investigators--

Same as data set C11A1.

Supporting Data

Same as data set C11A1.

DATA SET C11B1: WATER TEMPERATURE MONITORING AT THE FIVE FISH MONITORING STATIONS AT THE COLUMBIA GENERATING STATION SITE (1976-78)

DATA SUMMARY

Abstract--

This data set contains records of water temperature measurements at five stations in Rocky Run Creek, the ashpit drain, and the mint farm drain. There are records for stations 1-4 during the spring months of 1976-78. Records for station 5 were only obtained during 1978. The monitoring schedule was irregular. These data were used to determine whether unusually warm water temperatures existed that could stimulate early fish egg development and fry emigration from the marsh before other environmental conditions are optimal.

Dates of Research--

5 March 1976 through 16 April 1978.

Data Form--

Computer file containing 78 units with one card-image/unit.

Data Format

Field Description--

<u>Column</u>	<u>Format</u>	<u>Description</u>
1-2	I2	Month
3-4	I2	Day
5-6	I2	Year
8-9	I2	Site (01)
11-14	F4.1	Water temperature site 1 (°C)
16-17	I2	Site (02)
19-22	F4.1	Water temperature site 2 (°C)
24-25	I2	Site (03)
27-30	F4.1	Water temperature site 3 (°C)
32-33	I2	Site (04)
35-38	F4.1	Water temperature site 4 (°C)
40-41	I2	Site (05)
43-46	F4.1	Water temperature site 5 (°C)

Missing Data--

Missing data are indicated by 999.

Data Sample

The sample presented here is 15 records, 5 to 20, of the 78 records in data set C11B1.

12345678901234567890123456789012345678901234567890

031676	01	1.7	02	1.3	03	1.0	04	3.7	05	999
031776	01	2.0	02	2.2	03	1.8	04	4.2	05	999
031876	01	4.7	02	5.0	03	3.8	04	7.5	05	999
031976	01	4.5	02	6.6	03	3.6	04	8.6	05	999
032076	01	4.8	02	5.7	03	7.7	04	10.4	05	999
032176	01	3.4	02	3.6	03	3.4	04	3.6	05	999
032276	01	999	02	3.6	03	5.0	04	7.5	05	999
032376	01	3.1	02	3.5	03	3.1	04	4.5	05	999
032476	01	6.0	02	7.0	03	5.8	04	7.2	05	999
032576	01	7.0	02	7.2	03	6.1	04	6.7	05	999
032676	01	9.2	02	8.5	03	6.5	04	10.6	05	999
032776	01	6.3	02	6.3	03	4.5	04	6.5	05	999
032876	01	999	02	6.8	03	5.1	04	7.7	05	999
033176	01	999	02	6.4	03	6.4	04	7.0	05	999
040176	01	999	02	4.0	03	999	04	6.1	05	999

Quality Assurance

Objectives--

In the seventh semi-annual progress report, the hydrogeology subproject reported that a thermal gradient existed in the groundwater beneath the

sedge meadows, caused by seepage from the cooling lake. The purpose of the study was to determine whether unusually warm water temperatures existed in the spawning marsh that could stimulate early fish egg development and fry emigration from the marsh before other environmental conditions were optimal. From studying these data, the experimenters concluded that the net site temperatures were within 1°C of the Wisconsin River water temperature so that a further study of thermal influence in fry development was unnecessary. Wisconsin River temperatures were obtained from the U.S. Geological Survey.

Monitoring Sites--

Refer to data set C11A1.

Monitoring Procedure and Equipment--

Water temperature readings were obtained with a glass-mercury thermometer that had an accuracy of $\pm 1^{\circ}\text{C}$. Readings were obtained in mid-channel at a depth of 6 inches. Only one measurement was made to obtain each reading included in the data. The temperature measurements, made during spring 1976 in an effort to locate the thermal gradient in the marsh, demonstrated the overriding influence of the flood waters. Water temperatures recorded were uniform and were within 1°C of the Wisconsin River water temperature. Approaches to test the thermal influences on fry production were thus considered unnecessary.

Investigators--

Same as data set C11A1.

Supporting Documents

Same as data set C11A1.

SECTION 12

ASSESSMENT OF A COOLING LAKE ECOSYSTEM

This subproject examined temporal and spatial limitations for organisms evolved in temperate lakes when they were subjected to the elevated thermal conditions of the cooling lake at the Columbia Generating Station. The principal goals were to monitor specific biological responses of organisms important for a thorough assessment of the fisheries potential of the cooling lake and to investigate the opportunity for research and development of fish management strategies specific to cooling lakes.

Specific objectives were: (1) to determine the abundance, distribution and behavioral strategies of organisms representative of various trophic levels in relation to seasonal changes in thermal and chemical gradients in the cooling lake and (2) to study changes in the abundance, spatial distribution, and growth and reproductive responses of fish when subjected to elevated thermal gradients in the cooling lake.

Relating to objective (1), five studies were conducted. The data collected are presented in data sets C12A1, C12A2, C12A3, and C12A4. Data set C12A1 (Water temperature monitoring in the cooling lake of the Columbia Generating Station (1975-76)) presents records of temperature monitoring at 19 stations in the cooling lake at approximately 2-week intervals. Data set C12A2 (Current velocity monitoring at three depths in the cooling lake of the Columbia Generating Station (August 1976)) presents records of current velocity monitoring on 23 Aug. 1976 at 11 stations in the cooling lake at depths of 0.5, 1.0, and 2.0 m. Data set C12A31 (Chlorophyll content of two types of algae) presents data which were used to estimate gross primary production of biomass in the cooling lake. Data set C12A32 (Light extinction in the cooling lake of the Columbia Generating Station (1975-76)) presents records of the extinction coefficient of light and of total surface radiation, which were used to estimate photosynthetic production for algae in the cooling lake. Data set C12A4 (Abundance and distribution of three invertebrates in the cooling lake (1976)) presents records of abundance, and head capsule lengths, for *Hyalella azteca* specimens and total lengths of specimens of two other invertebrate species obtained in the cooling lake.

Relating to objective (2), two studies were conducted. The data collected are presented in data sets C12B1 and C12B2. Data set C12B1 (Species diversity, distribution and growth of selected fish species in the cooling lake (1975-78)) presents records of specimen size and maturity for fish of 23 species obtained in fyke net catches in the cooling lake. Data set C12B2 (Distribution patterns of larvae and early juvenile fish sampled in the cooling lake of the Columbia Generating Station (1977-78)) presents

records of catch and size information on larval and early juvenile fish caught with two types of samplers in the Columbia cooling lake.

The investigators are James F. Kitchell, Associate Professor; Stephen Lozano, Research Assistant; and Dennis Rondorf, Research Assistant; Department of Zoology, University of Wisconsin-Madison. The report was compiled by Hilary McLellan, Data Analyst, Water Resources Center.

DATA SET C12A1: WATER TEMPERATURES IN THE COOLING LAKE OF THE COLUMBIA GENERATING STATION (1975-76)

Data Summary

Investigators--

S. Lozano and J. Kitchell.

Abstract--

This data set contains records of water temperatures ($^{\circ}\text{C}$) at a depth of 0.5 m in the cooling lake of the Columbia Generating Station. Water temperatures were monitored at 19 stations from June 1975 to December 1976 at approximately 2-week intervals. The study was designed to document water temperature patterns in the cooling lake since temperature is a major environmental factor influencing the life history and distribution of aquatic invertebrates.

Date of Research--

June 1975-Dec. 1976.

Data Form--

Computer file containing 35 units with four card-images/unit.

Data Format

Field Description--

Card #1

<u>Column</u>	<u>Format</u>	<u>Description</u>
1-2	I2	Day
3-4	I2	Month
5-6	I2	Year
8-11	F4.1	Water temperature 5300 m from outfall ($^{\circ}\text{C}$)
15-18	F4.1	Water temperature 5100 m from outfall ($^{\circ}\text{C}$)
22-25	F4.1	Water temperature 4900 m from outfall ($^{\circ}\text{C}$)
29-32	F4.1	Water temperature 4400 m from outfall ($^{\circ}\text{C}$)
35	I1	Card image number

Card #2

1-4	F4.1	Water temperature 3900 m from outfall (°C)
8-11	F4.1	Water temperature 3400 m from outfall (°C)
15-18	F4.1	Water temperature 2900 m from outfall (°C)
22-25	F4.1	Water temperature 2700 m from outfall (°C)
29-32	F4.1	Water temperature 2500 m from outfall (°C)
35	I1	Card image number

Card #3

1-4	F4.1	Water temperature 2000 m from outfall (°C)
8-11	F4.1	Water temperature 1700 m from outfall (°C)
15-18	F4.1	Water temperature 1300 m from outfall (°C)
22-25	F4.1	Water temperature 1000 m from outfall (°C)
29-32	F4.1	Water temperature 800 m from outfall (°C)
35	I1	Card image number

Card #4

1-4	F4.1	Water temperature 500 m from outfall (°C)
8-11	F4.1	Water temperature 400 m from outfall (°C)
15-18	F4.1	Water temperature 300 m from outfall (°C)
22-25	F4.1	Water temperature 200 m from outfall (°C)
29-32	F4.1	Water temperature 100 m from outfall (°C)
35	I1	Card image number

Missing Data--

Missing data are indicated by 9999.

Data Sample

The sample presented here is 2 units, 1 to 2, of the 35 units included in the complete data set C12A1.

12345678901234567890123456789012345

240675	29.5	29.9	30.4	30.8	1
31.2	31.8	33.3	33.6	33.9	2
34.8	35.8	35.8	35.8	37.5	3
9999	40.5	40.6	40.0	40.0	4
090775	26.9	26.9	27.0	27.4	1
27.6	28.1	28.6	28.6	28.8	2
30.1	32.3	33.2	34.4	35.3	3
36.0	38.4	38.6	39.9	41.0	4

Quality Assurance

Objectives--

The purpose of the study was to document water temperature patterns in the cooling lake of the Columbia Generating Station. Temperature is one of

the most important environmental factors influencing the life history and distribution of aquatic invertebrates.

Monitoring Sites--

Sites were chosen throughout the cooling lake (Figure 23) to document water temperature and current patterns, as the water flowed between the intake and outfall channels. Temperatures were monitored at 19 stations, located at increasing distances from the outfall channel: 100, 200, 300, 400, 500, 800, 1,000, 1,300, 1,700, 2,000, 2,500, 2,700, 2,900, 3,400, 3,900, 4,400, 4,900, 5,100, and 5,300 m.

Cooling water is removed from the cooling lake at the intake channel and pumped through the power plant condensers where temperatures are raised 15°C. Heated effluent flows from the outfall channel at a rate of 750 m³/min. and circulates around the center baffle dike back to the intake channel in approximately 5 days. Current velocity and heat decline exponentially as water flows from outfall to intake channel. Current velocity increases as flow is constricted near the settling basin and intake.

Monitoring Equipment and Procedures--

Temperature readings were taken from June 1975 to Dec. 1976 at approximately 2-week intervals. To obtain temperature readings, a Montedoro Whitney CTU-3B conductivity-temperature meter was lowered to a 0.5 m depth from a 6 m flat-bottom aluminum boat.

The Montedoro Whitney CTU-3B meter was equipped with an internal, battery operated calibration mechanism. The meter was calibrated to $\pm 0.1^\circ\text{C}$ at the beginning and end of each season. It was checked using standard thermometers and a Landa K 2/R heating-cooling bath at 5°C intervals between 0° and 40°C.

Investigators--

The investigation was conducted by Stephen Lozano. At the time of the investigation, he was working toward a Ph.D. in Zoology at the University of Wisconsin-Madison under the supervision of Dr. James F. Kitchell.

Supporting Documents

Kitchell, James F., Stephen J. Lozano, and Dennis Rondorf. 1977. Assessment of a cooling lake ecosystem. In: Documentation of environmental change related to the Columbia Electric Generating Station. Institute for Environmental Studies, Report 92, University of Wisconsin-Madison. p.p. 90-93

Kitchell, J. F. Limnology, biology, and stability of a cooling lake. U.S. Environmental Protection Agency, Cincinnati, Ohio. In press.

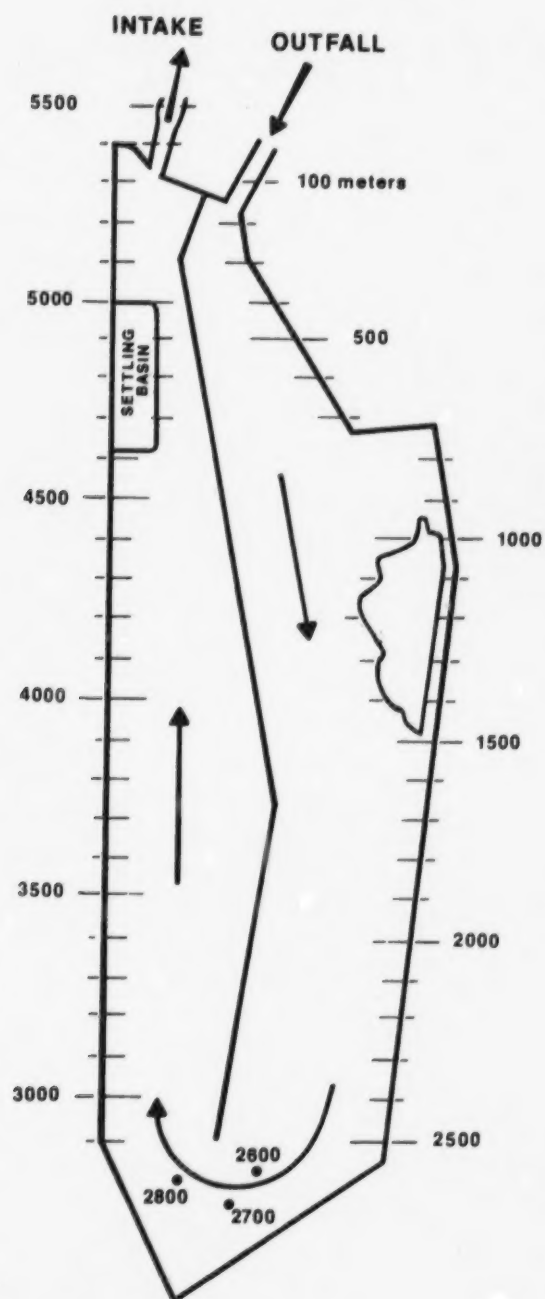


Figure 23. Sampling stations in the cooling lake of the Columbia Generating Station.

Lozano, S. J., Dennis W. Rondorf, and J. F. Kitchell. 1978. Assessment of a cooling lake ecosystem. Water Resources Center Technical Report WIS WRC 78-08, University of Wisconsin-Madison. 108 p.

Lozano, S. J., and J. F. Kitchell. 1977. Response of a mobile invertebrate to heterothermal conditions. Presented at the Savannah River Ecology Symposium, Augusta, Georgia, Nov. 1977.

DATA SET C12A2: CURRENT VELOCITIES AT THREE DEPTHS IN THE COOLING LAKE OF THE COLUMBIA GENERATING STATION (AUGUST 1976)

Data Summary

Investigators--

S. Lozano and J. Kitchell

Abstract--

This data set contains records of current velocities (cm/sec) in the cooling lake of the Columbia Generating Station. Current velocities were measured for three depths (0.5, 1.0, and 2.0 m) at 11 stations on 23 July 1976, supplementing data set C12A1.

Date of Research--

23 July 1976.

Data Form--

Computer file containing 14 units with one card-image/unit.

Data Format

Field Description--

<u>Column</u>	<u>Format</u>	<u>Description</u>
1-2	I2	Day
3-4	I2	Month
5-6	I2	Year
9-11	I3	Station in 100's of m from outfall
14-16	I3	x-component of current at 0.5 m depth ¹⁶
19-21	I3	y-component of current at 0.5 m depth
24-26	I3	x-component of current at 1.0 m depth

¹⁶The x-component of the current was perpendicular to the direction of flow of the current and the y-component was parallel.

29-31	I3	y-component of current at 1.0 m depth
34-36	I3	x-component of current at 2.0 m depth
39-41	I3	y-component of current at 2.0 m depth

Missing Data--

Missing data are indicated by 99.

Data Sample

The sample presented here is the complete data set C12A2.

12345678901234567890123456789012345678901

230776	01	17	06	99	99	18	07
230776	01	12	11	99	99	16	00
230776	01	17	05	99	99	06	15
230776	01	16	07	99	99	08	15
230776	02	12	05	10	08	02	02
230776	04	11	02	06	05	06	03
230776	05	01	07	07	02	01	03
230776	06	06	01	03	02	02	03
230776	08	03	02	03	02	03	02
230776	13	03	02	04	01	02	00
230776	22	06	04	05	01	04	02
230776	27	03	01	02	01	02	00
230776	34	02	03	02	01	02	01
230776	39	01	02	03	01	01	02

Quality Assurance

Objectives--

- The purpose of the study was to document water current patterns in the cooling lake. Data concerning current velocities were necessary to understand heated effluent flows from the outfall channel, around the center dike and back to the intake channel. Current velocity and water temperature data together provide an understanding of the temporal and spatial thermal gradient in the cooling lake and contribute to identifying temporal patterns and spatial limitations of selected fish and aquatic invertebrates.

Monitoring Sites--

The monitoring sites for this study (Figure 23) correspond to 11 of the 19 monitoring sites described in Data Set C12A1. These 11 sites were located at increasing distances from the outfall: 100, 200, 400, 500, 600, 800, 1,300, 2,200, 2,700, 3,400, and 3,900 m.

Monitoring Equipment and Procedures--

To obtain current velocity readings, a Marsh McBirney 711j current meter was lowered from a 6 m flat bottom aluminum boat to 3 depths (0.5, 1.0, and 2.0 m). To test the reliability of the readings, four sets of readings were obtained at the first site. These readings are included in

the data. There is only one set of readings for each of the other sites. The current meter was calibrated to 1 cm/sec at the beginning and end of each season.

Investigators--

Same as data set C12A1.

Supporting Documents--

Same as data set C12A1.

DATA SET C12A31: CHLOROPHYLL CONTENT OF PERIPHYTON AND PHYTOPLANKTON FROM THE COOLING LAKE OF THE COLUMBIA GENERATING STATION (1975-77)

Data Summary

Investigators--

S. Lozano and J. Kitchell

Abstract--

This data set contains records of chlorophyll content of two types of algae from the cooling lake. Periphyton samples were collected at six near-shore stations around the cooling lake and phytoplankton were collected at six open water stations perpendicular to the periphyton sampling stations. The periphyton samples were collected on five occasions and the phytoplankton on four occasions during the sampling period (Nov. 1976 to Sept. 1977). These data, together with data on light extinction and surface radiation (data set C12A32), were used to estimate gross production of biomass along the thermal gradient in the cooling lake.

Date of Research--

Nov. 1976-Sept. 1977

Data Form--

Computer file containing 9 units with six card-images/ unit.

Data Format

Field Description--

<u>Column</u>	<u>Format</u>	<u>Description</u>
1-1	I2	Day
3-4	I2	Month
5-6	I2	Year

8	I1	Sample code; 1=Limnetic chlorophyll sample;
		2= Periphytic chlorophyll sample
11-12	I2	Distance from the outfall (in 100's of m)
14-18	F5.3	Light absorbance in 3 ml cell at 663 m
20-24	F5.3	Light absorbance in 3 ml cell at 750 m
26-30	F5.3	Light absorbance in 3 ml cell at 663 m after adding 4 N HCL
32-36	F5.3	Light absorbance in 3 ml cell at 750 m after adding 4 N HCL

Missing Data--

No missing data.

Data Sample

The sample presented here is 2 units, 1 to 2, of the 9 units included in data set C12A31.

12345678901234567890123456789012345678901234567890

111176	1	04	.107	.012	.049	.001
111176	1	11	.082	.001	.043	.003
111176	1	18	.097	.008	.046	.001
111176	1	25	.101	.009	.053	.007
111176	1	39	.156	.027	.090	.002
111176	1	44	.037	.002	.024	.008
151276	1	04	.102	.020	.048	.007
151276	1	11	.107	.035	.048	.012
151276	1	18	.103	.037	.043	.010
151276	1	25	.198	.098	.069	.013
151276	1	39	.140	.068	.047	.011
151276	1	44	.097	.040	.028	.011

Quality Assurance

Objectives--

The purpose of the study was to provide data necessary to estimate gross production of biomass along the thermal gradient in the cooling lake. Photosynthetic production for periphyton and phytoplankton was estimated from chlorophyll content, together with the extinction coefficient of light and total surface radiation (data set C12A32).

Sampling Sites--

Periphyton samples were collected at six sampling points (Figure 23) along the shore of the cooling lake. The six stations were located at increasing distances from the outfall channel: 400, 1,100, 1,800, 2,500, 3,900 and 4,400 m. Phytoplankton samples were collected 50 to 100 m from the shore of the cooling lake at locations perpendicular to the periphyton

sampling points near the shore. Sampling stations were chosen throughout the cooling lake, representative of the different patterns of water temperature and current velocity characteristic of the circulation in the cooling lake.

Sampling Equipment and Procedures--

Periphyton (near shore algae) was sampled with vertically held glass slides. Glass slides were placed in holders at the six sites and left for colonization for 2 weeks, preserved in 50% Formalin Alcohol and Acidic solution (Vollenwieder, 1969).

To monitor phytoplankton species abundance and composition, limnetic water samples were collected in Van Doren bottles from Nov. 1976 to March 1977 and in Sept. 1977. The samples were stored in acid-washed polyethylene containers.

Analytical Procedures--

In laboratory experiments, periphyton and phytoplankton biomass estimates were made by means of chlorophyll determination. Methods for chlorophyll determinations are described in the IBP Handbook No. 8, Methods for Chemical Analysis of Freshwater (Golterman 1969).

For phytoplankton (limnetic) chlorophyll, 0.25 liter of water was filtered to obtain a condensed sample for analysis. For the periphytic chlorophyll, a condensed sample was obtained by scraping 9.5 cm² from a glass slide and filtering it. The filtered samples were ground and centrifuged. The extinction of supernatant was measured at 663 m in 3 ml cells on a Beckman model 990 spectrophotometer. After adding 0.1 ml of 4 N HCL, extinction of the centrifuged supernatant was remeasured at 663 m and 750 m. The Beckman Model 990 spectrophotometer was checked with known standards before each use.

The quantity of chlorophyll (P) was calculated:

$$P_{\text{limnetic}} = 546.07 (u_{E663} - u_{E750}) - (A_{E663} - A_{E750}) \text{ in mg/m}^3 \quad (5)$$

$$P_{\text{periphytic}} = 14.37 (u_{E663} - a_{750}) - (A_{E663} - A_{E750}) \text{ in mg/m}^3 \quad (6)$$

where u_{E663} and u_{E750} , extinction of supernatant at 663 and 750 m

A_{E663} and A_{E750} , extinction of supernatant after adding acid at 663 and 750 m.

Investigators--

Same as data set C12A1.

Supporting Documents

Same as data set C12A1.

DATA SET C12A32: LIGHT EXTINCTION IN THE COOLING LAKE OF THE COLUMBIA
GENERATING STATION (1976)

Data Summary
Investigators--

S. Lozano and J. Kitchell.

Abstract--

This data set contains records of light extinction measurements (ft candles) obtained at the cooling lake of the Columbia Generating Station. On 25 Aug. 1976, measurements for light extinction were made at five depths (0.1, 0.6, 1.1, 1.6, and 2.1 m) at each of the six open-water phytoplankton sampling stations (data set C12A31). The purpose of the measurements was to estimate the gross production of biomass along the thermal gradient in the cooling lake.

Date of Research--

Aug. 1976.

Data Form--

Computer file containing six units with one card-image/unit.

Data Format

Field Description--

<u>Column</u>	<u>Format</u>	<u>Description</u>
1-2	I2	Day
3-4	I2	Month
5-6	I2	Year
11-12	I2	Station in 100's of m from outfall
17-20	I4	Light extinction at 0.1 m depth (ft candles)
24-27	I4	Light extinction at 0.6 m depth (ft candles)
31-34	I4	Light extinction at 1.1 m depth (ft candles)
38-41	I4	Light extinction at 1.6 m depth (ft candles)
45-48	I4	Light extinction at 2.1 m depth (ft candles)

Data Samples

The sample presented here is the complete data set C12A32.

12345678901234567890123456789012345678901234567890

250876	51	5796	897	376	88	21
250876	39	5796	1231	358	122	38
250876	26	5319	1135	486	122	25
250876	20	5202	1031	458	125	43
250876	17	5319	1031	254	137	40
250876	05	5319	989	340	93	25

Quality Assurance

Objectives--

The purpose of the study was to provide data necessary to estimate gross production of biomass along the thermal gradient in the cooling lake. The extinction coefficient of light and total surface radiation, together with chlorophyll content (Data Set C12A31) were used to estimate photosynthetic production for periphyton and phytoplankton.

Sampling Sites--

Underwater light and surface radiation were measured at the six deepwater phytoplankton sampling stations (Data Set C12A31) 50 to 100 m from the shore of the cooling lake.

Sampling Equipment and Procedures--

At each station, light extinction measurements for five depths (0.1, 0.6, 1.1, 1.6, and 2.1 m) were obtained on 25 Aug. 1976 with a silver-selenite barrier-layer photometer. This instrument had an accuracy of 90%. Surface radiation at the six stations was measured during all underwater light measurements, with a Cds light meter. This parameter remained the same--9,900 ft candles--throughout the study. The Cds light meter had an accuracy of 20%. These instruments were calibrated at the lake laboratory at the University of Wisconsin-Madison where it was designed and built. Methods for calculations of percent transmission and vertical extinction coefficients of light were taken from Vollenweider (1969).

Investigators--

Same as data set C12A1.

Supporting Documents--

Same as data set C12A1.

DATA SET C12A4: ABUNDANCE AND DISTRIBUTION OF *HYALELLA AZTECA*, *CYPRODOPSIS VIDUA* AND *PHYSOCYPRIA PUSTULOSA* IN THE COOLING LAKE OF THE COLUMBIA GENERATING STATION (1975-76)

Data Summary

Investigators--

S. Lozano and J. Kitchell.

Abstract--

This data set contains records of the abundance and distribution of three species of aquatic invertebrates caught at 10 locations in the cooling

lake of the Columbia Generating Station. Samples of the amphipod *Hyaletta asteca* and the ostracods *Cyprodopsis vidua* and *Physocypria pustulosa* were obtained monthly from Aug. 1975 to Aug. 1976 and were monitored for abundance and distribution. In addition, from Aug. to Nov. 1975, *Hyaletta asteca* were measured for head capsule length (mm) and number of antennal segments.

Dates of Research--

Aug. 1975-Aug. 1976.

Data Form--

Computer files containing 488 units with one card-image/unit.

Data Format

Field Description--

These data are stored in three files.

File 1

<u>Column</u>	<u>Format</u>	<u>Description</u>
1-2	I2	Month
3-4	I2	Year
6-7	I2	Distance from outfall in hundred meters; Site 99=Settling Basin
9-13	I5	Count of <i>Hyaletta asteca</i> in Sampler #1
15-19	I5	Count of <i>Hyaletta asteca</i> in Sampler #2
21-25	I5	Count of <i>Hyaletta asteca</i> in Sampler #3
27-31	I5	Count of <i>Cyprodopsis vidua</i> in Sampler #1
33-37	I5	Count of <i>Cyprodopsis vidua</i> in Sampler #2
39-43	I5	Count of <i>Cyprodopsis vidua</i> in Sampler #3
45-49	I5	Count of <i>Physocypria pustulosa</i> in Sampler #1
51-55	I5	Count of <i>Physocypria pustulosa</i> in Sampler #2
57-61	I5	Count of <i>Physocypria pustulosa</i> in Sampler #3

File 2

1-2	I2	Month
3-4	I2	Year
6-8	F3.2	Head capsule length (mm) of <i>H. Asteca</i> caught at 5,100 m from the outfall
12-14	F3.2	Head capsule length (mm) of <i>H. Asteca</i> caught at 4,400 m from outfall
18-20	F3.2	Head capsule length (mm) of <i>H. Asteca</i> caught at 3,900 m from outfall
24-26	F3.2	Head capsule length (mm) of <i>H. Asteca</i> caught at 3,200 m from outfall

30-32	F3.2	Head capsule length (mm) of <i>H. Azteca</i> caught at 2,500 m from outfall
36-38	F3.2	Head capsule length (mm) of <i>H. Azteca</i> caught at 2,200 m from outfall
42-44	F3.2	Head capsule length (mm) of <i>H. Azteca</i> caught at 1,500 m from outfall
48-50	F3.2	Head capsule length (mm) of <i>H. Azteca</i> caught at 1,000 m from outfall
54-56	F3.2	Head capsule length (mm) of <i>H. Azteca</i> caught at 500 m from outfall

File 3

<u>Column</u>	<u>Format</u>	<u>Description</u>
1-2	I2	Month
3-4	I2	Year
6-8	F3.2	Head capsule length (mm) of <i>H. Azteca</i> with 15 anterior segments
11-13	F3.2	Head capsule length (mm) of <i>H. Azteca</i> with 16 anterior segments
16-18	F3.2	Head capsule length (mm) of <i>H. Azteca</i> with 17 anterior segments
21-23	F3.2	Head capsule length (mm) of <i>H. Azteca</i> with 18 anterior segments
26-28	F3.2	Head capsule length (mm) of <i>H. Azteca</i> with 19 anterior segments
31-33	F3.2	Head capsule length (mm) of <i>H. Azteca</i> with 20 anterior segments
36-38	F3.2	Head capsule length (mm) of <i>H. Azteca</i> with 21 anterior segments
41-43	F3.2	Head capsule length (mm) of <i>H. Azteca</i> with 22 anterior segments
46-48	F3.2	Head capsule length (mm) of <i>H. Azteca</i> with 23 anterior segments
51-53	F3.2	Head capsule length (mm) of <i>H. Azteca</i> with 24 anterior segments

Missing Data--

Missing Data are indicated by 9999 in file 1. There are no missing data in files 2 and 3. In file 2, zeroes indicate absence of *H. Azteca* at locations showing this reading. In file 3, 999 indicates absence of *H. Azteca* in antennal segment categories showing this reading.

Data Sample

The sample presented here is 12 records, 21 to 32, of the 124 records included in data set C12A41, file 1.

1234567890123456789012345678901234567890123456789012345678901234567890

1075	99	136	158	106	9999	9999	9999	9999	9999	9999
1075	51	524	474	522	169	120	93	57	34	25
1075	44	4	3	3	200	296	202	68	125	78
1075	39	5	3	7	172	231	199	84	65	89
1075	32	2	0	4	125	139	107	46	23	15
1075	25	4	0	1	79	79	103	39	31	53
1075	22	2	1	3	101	184	247	28	53	105
1075	15	1	0	1	343	392	181	53	71	51
1075	10	0	2	1	304	197	650	71	51	122
1075	05	9999	9999	9999	150	97	157	48	38	44
1175	99	102	146	116	9999	9999	9999	9999	9999	9999

The sample presented here is 15 records, 198 to 209, of the 303 records included in data set C12A41, file 2.

12345678901234567890123456789012345678901234567890123456789012345

1175	418	778	539	422	768	544	451	494	644
1175	453	729	571	518	504	505	473	436	781
1175	422	466	500	505	740	493	707	492	0
1175	420	457	474	707	498	544	463	636	0
1175	458	466	731	472	429	494	582	640	0
1175	418	422	419	671	681	484	660	457	0
1175	420	500	592	663	555	602	734	0	0
1175	464	402	499	544	721	0	489	0	0
1175	407	464	563	649	932	0	713	0	0
1175	469	504	427	627	514	0	661	0	0
1175	493	570	438	441	466	0	432	0	0
1175	469	743	507	469	402	0	701	0	0

The sample presented here is 12 records, 1 to 12, of the 61 records included in the complete data set C12A41, file 3.

12345678901234567890123456789012345678901234567890123456789012345

0875	346	381	351	379	399	485	483	506	559	582
0875	999	380	369	427	396	470	447	519	536	593
0875	999	386	371	371	445	439	473	463	549	999
0875	999	350	368	425	422	450	456	507	571	999
0875	999	348	373	388	386	999	999	511	489	999
0875	999	286	358	402	408	999	999	999	523	999
0875	999	227	355	419	395	999	999	999	999	999
0875	999	310	999	999	426	999	999	999	999	999
0875	999	999	999	999	469	999	999	999	999	999
0875	999	999	999	999	435	999	999	999	999	999
0975	340	341	400	477	431	440	594	640	650	701
0975	367	368	369	441	465	547	571	597	678	695

Quality Assurance

Objectives--

The purpose of the study was to provide data to estimate the abundance and distribution of three invertebrate species in the cooling lake in relation to annual changes in thermal and chemical gradients.

Sampling Sites--

Hyalella azteca, *Cyrodopsis vidua*, and *Physocypris pustulosa* were sampled at 10 sites. One site was in the settling basin. The other nine sites were located 300 to 700 m apart at increasing distances from the outfall channel: 500, 1,00, 1,500, 2,200, 2,500, 3,200, 3,900, 4,400, and 5,100 m.

Sampling Equipment and Procedure--

Thirty artificial substrate samplers, modified after Hester and Dendy (1962) were used in this study. These samplers consisted of six squares (64 cm²) of fiberboard alternating with five layers of conservation webbing. The samplers were presoaked before use. Three samplers were suspended 0.5 m below the surface at each sampling site in the cooling lake. The samplers remained suspended for a 2-week sampling period in each month from Aug. 1975 to Sept. 1976.

When collected, the samplers were placed in separate plastic bags filled with 90% ethanol. Organisms from all dates except Aug. 1976 were removed from the sampler, washed into a 0.28 mm mesh concentrator, and preserved in 70% ETOH. August 1976 samples were washed through a 0.07 mm mesh concentrator for young instar analysis since only the last two instars of ostracods are retained in a 0.28 mm mesh concentrator. Amphipods were separated from other invertebrates, cleared in xylene and mounted in Hoyer's solution on glass slides (Cooper 1965).

Amphipod abundance was recorded as number of specimens/sampler. Head length was measured with a Hewlett-Packard 9197A microprojector and digitizer along the dorsal margin from the posterior edge to the base of the first antennal segment. Antennal segment number was classified according to the total number of segments from the first and second antennae (Cooper 1965). Ostracod abundance/sampler was based on the entire sample, or quarter subsamples when ostracod density exceeded 2000 individuals/sampler. Species identifications were confirmed by L. D. Delorme of the Canadian Centre of Inland Waters.

The principle behind a substrate sampler is to leave it in the water long enough to reach equilibrium with the population of invertebrates in the surrounding natural waters. To characterize the invertebrate colonization of the modified Hester and Dendy samplers (the type of samplers used to collect the data in this data set), 10 of these samplers were suspended in Lake Mendota near the University of Wisconsin-Madison and sampled after different time intervals. These data are presented in Table 34. At Lake

Mendota, the 10 samplers were divided into groups of two. Each pair was set close together at a randomly selected location that was 50 m apart from every other pair of samplers. Each pair of samplers was left submerged for a different length of time to assess changes in the colonizing population related to the length of submergence time. On each of 5 days (days 1, 2, 8, 12, and 16), a pair of samplers was retrieved, stored and counted for 3 species of aquatic invertebrates

TABLE 35. INVERTEBRATE COLONIZATION OF THE MODIFIED
DESTER AND DENDY SAMPLERS

Submergence time (days)	Number of organisms					
	<i>C. vidua</i> *		<i>P. pustulosa</i> *		<i>H. Asteca</i> *	
	1	2	1	2	1	2
01	1172	1085	21	15	52	32
02	1037	1130	16	6	51	76
08	1443	1730	8	17	393	371
12	1782	1304	28	13	483	522
16	1724	1938	18	9	295	317

*Paired samplers at each site.

Investigators--

Same as data set C12A1.

Supporting Documents

Same as data set C12A1.

DATA SET C12B1: SPECIES DIVERSITY, DISTRIBUTION, AND GROWTH OF SELECTED FISH SPECIES IN THE COOLING LAKE OF THE COLUMBIA GENERATING STATION (1975-78)

Data Summary

Investigators--

D. Rondorf and J. Kitchell.

Abstract--

The data set contains records of fish catches at nine sampling stations in the cooling lake of the Columbia Generating Station. On 92% of the sampling dates, specimens of 23 fish species caught were monitored for total

length. Specimens of selected species within specific size limits were monitored for sex, maturity, total weight, and gonad weight. Records of water temperatures at depths of 0.5, 1.0, 1.5, and 2.0 m at the six stations also are included. Sampling was carried out on 55 sampling dates, monthly or more frequently during most of the study period.

Dates of Research--

July 1975-May 1978.

Data Form--Computer file containing 11,121 units with one card-image/unit.

Data Format

Field Description--

Column	Format	Description
1-2	I2	Year
3-4	I2	Month
5-6	I2	Day
8-10	I3	Fyke net site (distance in 100's of meters from outfall)
13-15	F3.1	Temperature at 0.5 m depth (°C)
18-20	F3.1	Temperature at 1.0 m depth (°C)
23-25	F3.1	Temperature at 1.5 m depth (°C)
28-30	F3.1	Temperature at 2.0 m depth (°C)
34-35	I2	Species code number; 1= <i>Lepomis macrochirus</i> , 2= <i>Lepomis gibbosus</i> , 3= <i>Pomoxis nigromaculatus</i> , 4= <i>Pomoxis annularis</i> , 5= <i>Micropterus salmoides</i> , 6= <i>Micropterus dolomieu</i> , 7= <i>Ambloplites rupestris</i> , 10= <i>Morone chrysops</i> , 20= <i>Dorsoma cepedianum</i> , 30= <i>Ictalurus melas</i> , 32= <i>Ictalurus natalis</i> , 33= <i>Ictalurus punctatus</i> , 40= <i>Cyprinus carpio</i> , 50= <i>Ictiobus cyrinellus</i> , 51= <i>Ictiobus bubalus</i> , 53= <i>Carpoides cyprinus</i> , 54= <i>Carpoides carpio</i> , 55= <i>Minytrema melamops</i> , 56= <i>Catastomus commersoni</i> , 57= <i>Catasomidae</i> , 60= <i>Esox lucius</i> , 71= <i>Perca flavescens</i> , 72= <i>Stizostedion vitreum</i>
38-40	I3	Total length (mm)
43-45	I3	Standard length (mm)
47-50	I4	Total wt of fish (g)
51-55	F5.2	Gonad wt (g)
57	I1	Sex of fish; 0=not determined, 1=male, 2=female, 3=immature
59	I1	Sexual maturity; 0=not determined, 1=virgin, 2=maturing virgin, 3=developing, early stage, 4=developing, later stage, 5=gravid, 6=spawning, 7=spawning/spent
61-64	I4	Number of fish of species counted and not measured

67-69 F3.2 Fulton's condition factor (KTL)
 71-75 F5.2 $GSI = \frac{\text{Gonad wt}}{\text{Total wt}} \times 100$

Missing data--

Missing data are indicated by zero except for missing temperature data which are indicated by 999.

Data Sample

The sample presented here is 12 records, 1,041 through 1,052, of the 11,121 units included in the complete data set C12B1.

123456789012345678901234567890123456789012345678901234567890															
761222	5	185	181	163	132	1	139	0	51	6	1	2	0	189	11
761222	5	185	181	163	132	1	154	0	74	11	1	2	0	202	14
761222	5	185	181	163	132	1	156	0	75	15	1	2	0	197	20
761222	5	185	181	163	132	1	140	0	63	9	1	2	0	229	14
761222	5	185	181	163	132	1	182	0	125	25	1	2	0	207	20
761222	5	185	181	163	132	1	167	0	90	21	1	2	0	193	23
761222	5	185	181	163	132	1	159	0	85	17	1	2	0	211	20
761222	5	185	181	163	132	1	162	0	83	129	2	2	0	195	155
761222	5	185	181	163	132	1	139	0	52	46	2	2	0	193	88
761222	5	185	181	163	132	1	165	0	88	99	2	2	0	195	112
761222	5	185	181	163	132	1	128	0	39	43	2	2	0	185	110
761222	5	185	181	163	132	1	185	0	135	198	2	2	0	213	146

Quality Assurance

Objectives--

This survey had three purposes: (1) to study changes in relative abundance of fish species as the newly impounded cooling lake at the Columbia Generating Station progressed toward an equilibrium, (2) to determine spatial changes in the distribution of fishes when subjected to an elevated thermal gradient over various seasons, and (3) to study growth and reproductive response of fish in a small lake ecosystem with an elevated thermal input.

Sampling Sites--

Sampling was carried out at nine sampling stations in the cooling lake (Figure 23)--five at cool locations and four at warm locations. The four warm stations were located 500, 1,300, 1,700, and 2,200 m from the outfall. The five cool stations were located 3,300, 3,800, 4,500, 5,000, and 5,700 m from the outfall.

Sampling Procedures--

Fyke nets were constructed with 32-mm stretch mesh nylon webb, and equipped with a 15.2-m lead, 1.8-m frames, and five 0.75-m diameter hoops.

Nets were set perpendicular to shore. At the time the nets were set, water temperatures were taken at 0.5, 1.0, 1.5, and 2.0 m depths using a Montedoro-Whitney CTU-3B conductivity temperature meter. After 24 hr, the catch was gathered up. Individual specimens were identified by species using Eddy and Underhill (1974) and Scott and Crossman (1973) and measured for total length--the greatest length from the most anterior extremity to the end of the tailfin. A few specimens also were measured for standard length--from the most anterior extremity (mouth closed) to the hidden base of the median tail fin rays. All specimens were released, except on 48 sampling dates when selected specimens were frozen on dry ice and returned to the laboratory for further measurements. When the catch permitted, specimens were selected from stations on the warm side and the cool side of the cooling lake in equal numbers for paired comparison of the two parameters GSI and mean total length between warm and cool stations.

Laboratory Procedures--

In the laboratory, individual specimens were measured for total weight on an electronic balance. Some of these specimens obtained on each of 24 sampling dates were identified according to sex and eight stages of sexual maturity (Ricker 1971). The gonads were removed, blotted for 1 min. on an absorbent towel, and weighed to the nearest 0.01 g on an electronic balance.

Analytical Procedures--

In order to assess the weight-length relationship, the Fulton's condition factor (KTL) was estimated for some specimens. This condition factor is recorded in 0.01 units so that for a reading of 181,

$$\text{Condition factor} = 1.81K_{(TL)} = \frac{TW \times 105}{(TL)^3}.$$

The gonadosomatic index was determined for some specimens (gonad weight/total weight x 100).

Calibration--

The Montedoro-Whitney conductivity-temperature meter model CTU-3B was checked at the beginning and end of each field season. It was checked using standard thermometers and a Landa K 2/R heating-cooling bath at 5°C intervals between 0°C and 40°C. The electronic balance was reset at zero before each series of measurements.

Summary of the Data--

On 95% of the sampling dates, specimens of 23 fish species caught were monitored for total length. For 87% of the sampling dates, selected specimens (10 to 15 fish of each sex/date) were frozen and taken to the laboratory for further analyses.

Investigators--

The study was conducted by Dennis Rondorf. At the time of the experiment, he was working toward an M.S. degree in Oceanography and Limnology at the University of Wisconsin-Madison under the supervision of Professor J. Kitchell.

Supporting Documents

Same as data set C12A1.

DATA SET C12B2: DISTRIBUTION PATTERNS OF LARVAE AND EARLY JUVENILE FISH SAMPLED IN THE COOLING LAKE OF THE COLUMBIA GENERATING STATION (1977-78)

Data Summary

Investigators--

D. Rondorf and J. Kitchell.

Abstract--

This data set contains records of catch and size information on larvae and early juvenile fish caught in the cooling lake of the Columbia Generating Station. Two sampling methods were used. In the spring of 1977 and 1978, sampling was conducted with Miller samplers at 2-week (or shorter) intervals. During the 1977 season only (May through June) sampling with submerged plexiglass traps was conducted approximately weekly. These records were used to assess the larvae forms inhabiting the limnetic zones of lakes and to determine the temporal and spatial patterns of distribution of larvae and early juvenile fish in a cooling lake. Specifically, the records include the date, distance from the outfall at the start of the tow (100's of meters) distance from the outfall at the end of the tow (m), number of individual fish caught (by species), and total length for each individual fish. Supplementary data included tow length (m), time when tow started and ended (CST), time of sunset (CST) at Truax Field in Madison, WI, depth of tow, and water temperatures (°C) at depths of 0.5, 1.0, 1.5, and 2.0 m below the lake surface at the start and stop points of each tow.

Date of Research--

1977-1978.

Data Form--

Computer file containing 4,266 card images.

Data Format

Field Description--

There are three types of cards in each unit. The number of card-images/unit varies, depending upon the number of specimens caught and measured. The number of card-images per unit ranges between 6 and 26.

Card #1 - Tow Description Record

<u>Column</u>	<u>Format</u>	<u>Description</u>
1-2	I2	Year
3-4	I2	Month
5-6	I2	Day
8-9	I2	Tow number for day
10	I1	Sample number for tow
12	A1	Sample type; M=Miller tow, T=Light trap
14-15	I2	Beginning of tow, distance from outfall (100's of meters)
17-18 meters)	I2	End of tow, distance from outfall (100's of meters)
20-23	I4	Total length of tow (m); l=light traps are stationary
25-28	I4	Time sampling began (CDT)
30-33	I4	Time sampling completed (CDT)
35-38	I4	Time of sunset (CDT)
40-41	F2.1	Depth of sample (m)
43-45	F3.1	Water temperature at start of tow at 0.5 m below lake surface (°C)
47-49	F3.1	Water temperature at start of tow at 1.0 m below lake surface (°C)
51-53	F3.1	Water temperature at start of tow at 1.5 m below lake surface (°C)
55-57	F3.1	Water temperature at start of tow at 2.0 m below lake surface (°C)
59-61	F3.1	Water temperature at end of tow at 0.5 m below lake surface (°C)
63-65	F3.1	Water temperature at end of tow at 1.0 m below lake surface (°C)
67-69	F3.1	Water temperature at end of tow at 1.5 m below lake surface (°C)
71-73	F3.1	Water temperature at end of tow at 2.0 m below lake surface (°C)
77	I1	Number of species measured in this sample (4 cards follow for each species measured)
80	I1	Card image number

Card #2 - Species Counts

<u>Column</u>	<u>Format</u>	<u>Description</u>
1-2	I2	Year
3-4	I2	Month
5-6	I2	Day
8-9	I2	Tow number for day
10	I1	Sample number for tow
12-14	I3	<i>Morone</i> sp., number caught
16-18	I3	<i>Lepomis</i> sp., number caught
20-22	I3	<i>Pomoxis</i> sp., number caught
24-26	I3	<i>Micropterus</i> sp., number caught
28-30	I3	<i>Dorsoma cepedianum</i> , number caught
32-34	I3	<i>Ictalurus natalis</i> , number caught
36-38	I3	<i>Ictalurus punctatus</i> , number caught
40-42	I3	<i>Cyprinus carpio</i> , number caught
44-46	I3	<i>Notropis hudsonius</i> , number caught
48-50	I3	Cyprinidae (unidentified) number caught
52-54	I3	Catastomidae (unidentified) number caught
56-58	I3	Unknown species, number caught
80	I1	Card image number

Length Measurement Cards (4 cards per species measured)

<u>Column</u>	<u>Format</u>	<u>Description</u>
1-2	I2	Year
3-4	I2	Month
5-6	I2	Day
8-9	I2	Tow number for day
10	I1	Sample number for tow
12-13	I2	Species code#
15-16	I2	Number of specimens measured
18-77	15F4.1	Length measurements (mm) of specimens measured
80	I1	Card image number

Missing Data--

Missing data are indicated by 999 and 9999. When no temperature measurement was attempted by the investigators, it is indicated by 888. On the length measurement cards, zero indicates that no additional specimens were measured.

Data Sample

The sample presented here is 9 card-images, 2,183 to 2,191 of the 4,266 card-images included in the complete data set C12B2.

1234567890123456789012345678901234567890123456789012345678901234567890

780328	11	M	13	15	5000	1946	1952	1819	5	229	225	220	211	229	225	220	211	3	1
780328	11		1	0	0	0	30	0	0	0	0	2	0	0	0	0	0	0	0
780328	11	9	1	72	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
780328	11	9	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
780328	11	9	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
780328	11	9	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
780328	11	20	21	36	40	45	46	46	40	44	44	44	36	36	36	40	43	43	6
780328	11	20	21	50	48	86	46	42	38	0	0	0	0	0	0	0	0	0	7
780328	11	20	21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8
780328	11	20	21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9
780328	11	20	21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10

Quality Assurance

Objectives--

This study had two purposes: (1) to assess the relative reproductive success of adult fish of species (present in the cooling lake) known to have larval forms inhabiting the limnetic zones of lakes and (2) to determine the temporal and spatial patterns of distribution of larval and early juvenile fish in the cooling lake.

Sampling sites--

Sampling was carried out in the cooling lake of the Columbia Generating Station (Figure 23). Miller samples were towed along transects marked by lights. Tows were started at 15 points ranging from 500 to 4,500 m from the outfall. Tow lengths ranged from 200 to 1,000 m. The plexiglass traps were set at 11 locations; 500, 1,000, 1,500, 2,000, 2,400, 2,500, 3,600, 4,000, 4,500, 5,000, and 5,500 m from the outfall.

Sampling procedure--

The abundance of larval and early juvenile fish in the cooling lake was used as a measure of the reproductive success of fish present in that environment. Two types of sampling were carried out--sampling with high speed Miller samplers towed along transects and sampling with clear plexiglass traps submerged to a depth of 30 cm and left stationary for 2 hr at different points in the cooling lake.

During May-June 1977 the limnetic area of the lake was sampled using two Miller samplers (Miller 1961) towed by cable from ends of a 616 m boom mounted across a 6.1 m flat-bottom aluminum boat equipped with a 25 hp motor. During the next sampling season, between March and June 1978, the two Miller samplers were mounted at the ends of a separate 2.0-m heavy-duty pipes. The two pipes were mounted perpendicular to the ends of a 6.0-m boom so that the pipes and the two Miller samplers could be lowered to the selected sampling depth. The Miller samplers had collecting cups and

conical nets that were 90 cm in length. The mesh nitrex aperture size used in the samplers varied (0.25, 0.59, or 0.96 mm) depending on the date and size of fish. Samplers were towed along transects marked by lights. Each transect was completed half in the upstream direction and half in the downstream direction, giving the transect a U-shape.

Tows to assess horizontal distribution patterns were carried out between 1900 hr and 2400 hr CST with towing starting approximately 0.5 hr after the time of sunset in 1977 and 1 hr after sunset in 1978. Time of start and finish of tow were recorded to the nearest minute. The Miller tows were the primary sampling method for two reasons. The Miller samplers were assumed (1) to be less selective than the light traps and (2) to have the capacity to filter all water encountered. The filtration efficiency of Miller samplers is almost 100% even when they are as much as 75% clogged (Miller 1961, Noble 1970). The Miller samplers were used during the 1977 and 1978 sampling seasons.

During the 1977 season only, clear plexiglass light traps equipped with lights were used, in addition to the Miller tows, to collect larval fish in the cooling lake. The light traps, a modification from previous designs (Breder 1960, Casselman and Harvey 1973) were 30 x 30 x 15 x 27.5 cm in area. The traps each had a 0.1-amp light bulb in a 270-ml jar mounted on the trap with electrical wiring to a 6-volt dry cell on a styrofoam float. The traps were set at 30-cm depth for a period of 2 hr between 2100 and 2300 hr.

Larval and juvenile fish were preserved in the field in 10% formalin and later placed in 5% buffered formalin. Concurrent with the sampling, water-temperature readings were obtained at the sampling sites with a Montedoro-Whitney conductivity-temperature meter model CTV-3. Two Ryan 30°C span model G recording thermographs were used in 1977 and two Ryan recording thermographs in 1978 to continuously monitor diel-temperature changes. Daily-mean-intake temperatures calculated from readings at 4-hr time intervals were provided by the Columbia Energy Center and Wisconsin Power and Light, Inc. Current velocities were measured using a Marsh-McBirney Model 711 electromagnetic-water-current meter.

Calibration--

The Montedoro-Whitney conductivity-temperature meter model CTV-3 was calibrated to 0.1°C using a Landa K 2/R heating-cooling bath.

Analytical Procedure--

In the laboratory specimens were counted and identified under a binocular dissecting scope according to larvae keys and descriptions containing families known to be in the lake (Hogue et al. 1976, May and Gassaway 1967, Meyer 1970, Siefert 1969). A random subsample of not more than 60 specimens/sample in 1977 and not more than 30 specimens/sample in 1978 were measured. Postlarvae ≤ 15 mm were measured to the nearest 0.1 mm with an ocular micrometer and those > 15 mm were measured to the nearest mm.

on metric graph paper. The ocular micrometer was calibrated using a stage micrometer with 0.01 mm divisions.

Investigators--

Same as data set C12B1.

Supporting Documents

Same as data set C12B1.

REFERENCES

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SECTION 13

WETLAND BIRDS

The main goals of the Wetland Bird subproject have been to document the subtle and gross changes occurring in wetland bird population as they related to the construction and operation of the Columbia Generating Station. Changes at the site of the Columbia Generating Station, which is predominantly wetland, included direct changes caused by construction and indirect changes caused by vegetation changes and the creation of the cooling lake.

The specific objectives were (1) to determine the impact of the Columbia Generating Station on bird abundance and distribution on the site, (2) to document the effect of the power station on waterfowl and great blue herons; and (3) to improve understanding of the relationships of water regime, vegetation patterns, and bird populations.

In relation to objective (1), a bird survey was conducted on the site. The data are presented in data sets C13A1, C13A2, C13A3, C13A4, and C13A5. Data set C13A1 (A survey of abundance and distribution of birds at the Columbia site (1973-76)) documents the bird species population found in a five-transect system. The 88 observation stations of these transects were sampled regularly during 1973-76. Data set C13A2 (Key to species name and number code) is an auxiliary data set containing the name code of the bird species found in data sets C13A1 and C13A5. Data set C13A3 (Vegetation and disturbances in the bird observation stations) documents the major vegetation cover in the bird-observation sites. Data set C13A4 (Vegetation cover maps of the bird-survey observation stations) is an auxiliary data set to data sets C13A1 and C13A3 that includes maps of the observation stations. Data set C13A5 (Species observed at the Columbia site during 1974-76) documents qualitatively the changes in species composition on the Columbia site.

In relation to objective (2) two studies were conducted which are documented in data sets C13B1 and C13B2. Data set C13B1 (The study of waterfowl on the cooling lake of the Columbia Generating Station (1975-76)) documents the species and abundance of waterfowl during the peak of the migration season. Data set C13B2 (Population of the great blue heron rookery near the Columbia Generating Station (1974-77)) documents the decline in the nests found in the great blue heron rookery 1 mile northwest of the Columbia site.

In relation to objective (3) a study was conducted in the wetland west of the cooling lake. The data are presented in data sets C13C1 and C13C2. Data set C13C1 (The relationship of wetland birds to their habitat--the bird data (1975-78)) documents the population of breeding passerine birds in the area west of the cooling lake. Data set C13C2 (The relationship of wetland birds to their habitat--the vegetation and water data (1975-78)) documents the vegetation and water regime at the same sampling sites where the bird data were collected (data set C13C1).

The investigators were Daniel Willard, who at the time of the study was principal investigator of the Columbia Impact Study; William W. Jones, specialist; Barbara Bedford, specialist and later a research assistant; and Michael J. Jaeger, field worker, all at the Institute for Environmental Studies, University of Wisconsin-Madison. The report was compiled by Saya Shacham, Data Analyst in the Water Resources Center.

DATA SET C13A1:

A SURVEY OF ABUNDANCE AND DISTRIBUTION OF WETLAND BIRDS ON THE COLUMBIA GENERATING STATION SITE (1973-76)

Data Summary

Investigators--

W.W. Jones and D.E. Willard.

Abstract--

A 4-yr survey (1973-76) was conducted to determine the effects of the Columbia Generating Station on the bird population in an adjacent wetland. To record the changes a system of five transects was established in which each transect contained 17 or 18 stations. Each transect was surveyed once every 12 days from April through October of each year, and all birds observed in each station were recorded. Each record contains the population of each species observed in each station, the date, the sky condition, the wind, and the temperature. The key to species' names is in data set C13A2.

Dates of Research--

1973-76.

Data Form--

Computer file containing 4,017 units with one card-image/unit.

Data Format

Field Description--

<u>Column</u>	<u>Format</u>	<u>Description</u>
1-2	I2	Year of observation
3-4	I2	Month
5-6	I2	Day of observation
9	I1	Transect number
11-12	I2	Station number
14	I1	Sky condition during observation: 1=clear; 2=25% cloudy; 3=50% cloudy; 4=75% cloudy; 5=100% cloudy; 6=fog; 7=rain; 8=snow.
16	I1	Wind speed during observation: 1=calm; 2=0 to 5 (mph); 3=5 to 10 (mph); 4=10 to 15 (mph); 5=15 to 20 (mph).
18-19	I2	Temperature (*F)
21-23	I3	Bird identification number (See data set C13A2)
24-25	I2	Number of birds observed

Columns 21-25 repeated according to the number of observed species.

Data Sample

The sample presented here is 10 units, 1 to 10, of 4,016 units included in data set C13A1.

12345678901234567890123456789012345678901234

730401 2 01 5 3 40 56303 33101
730401 2 02 5 3 40 58102 76101
730401 2 03 5 3 40 58101 19402
730401 2 04 5 3 40 72702
730401 2 07 5 3 40 50901 31602
730401 2 08 5 3 40 50902
730401 2 09 5 3 40 76101
730401 2 10 5 3 40 72701
730401 2 11 5 3 40 40601
730401 2 12 5 3 40 58101

Quality Assurance

Objectives--

The goal of the survey was to determine the impact of construction of the Columbia Generating Station on existing bird life in the area. To document changes in bird populations, a systematic bird survey was conducted using a transect system which traversed all the habitats at the Columbia site.

Sampling Sites--

The transect system consists of 88 stations divided into five transects, each comprised of 17 or 18 stations. The five transects (Figure 24), each approximately 2 miles long, traverse all the site's plant communities (see also data set C13A3).

Transect 1--Located along the federal levee on the northern edge of the site near Portage; traverses southern wet forest (not included in Figure 24).

Transect 2--Located on the oak knoll at the southwest corner of the site; traverses southern wet forest and southern dry forest interspersed with patches of old field, sand barrens, sedge meadow, and shrub carr.

Transect 3--Located on the oak knoll between Duck Creek and the west dike of the cooling lake; traverses southern dry forest with considerable mixture of southern wet forest, old field, sand barrens, and shrub carr.

Transect 4--Located along the west dike of the cooling lake; extends along the shallow-water marsh and sedge meadow on the west and the cooling lake on the east.

Transect 5--Located along the railroad tracks paralleling the east dike of the cooling lake; encompasses a variety of vegetation types, including southern dry forest, southern wet forest, shallow-water marsh, shrub carr, and tamarack bog.

Transects 1, 4, and 5 have 18 observing stations, while transects 2 and 3 have 17 observing stations.

Two station shapes were used in the transect system. In the woods a square-shaped station (50 x 50 m) with the trail down the middle, was preferred and was used in transects 2 and 3. For transects 1, 4, and 5, a rectangular-shaped station was used (33.33 x 75 m). Both station shapes had an area of 2,500 m². This size was best since it was small enough to be sampled accurately yet large enough to include birds with relatively large territories.

Observation Schedule--

The goal was to observe each station weekly from 1973 through 1976. Personnel problems and weather conditions, however, prevented the achievement of this goal. From April through October each transect was walked and observed on average every 12 days. The attempt also was made to obtain equal numbers of observations in each transect. Spring flooding prevented observation of some transects for a period of 2-3 weeks. Conversely, during peak construction periods each transect was observed more frequently.

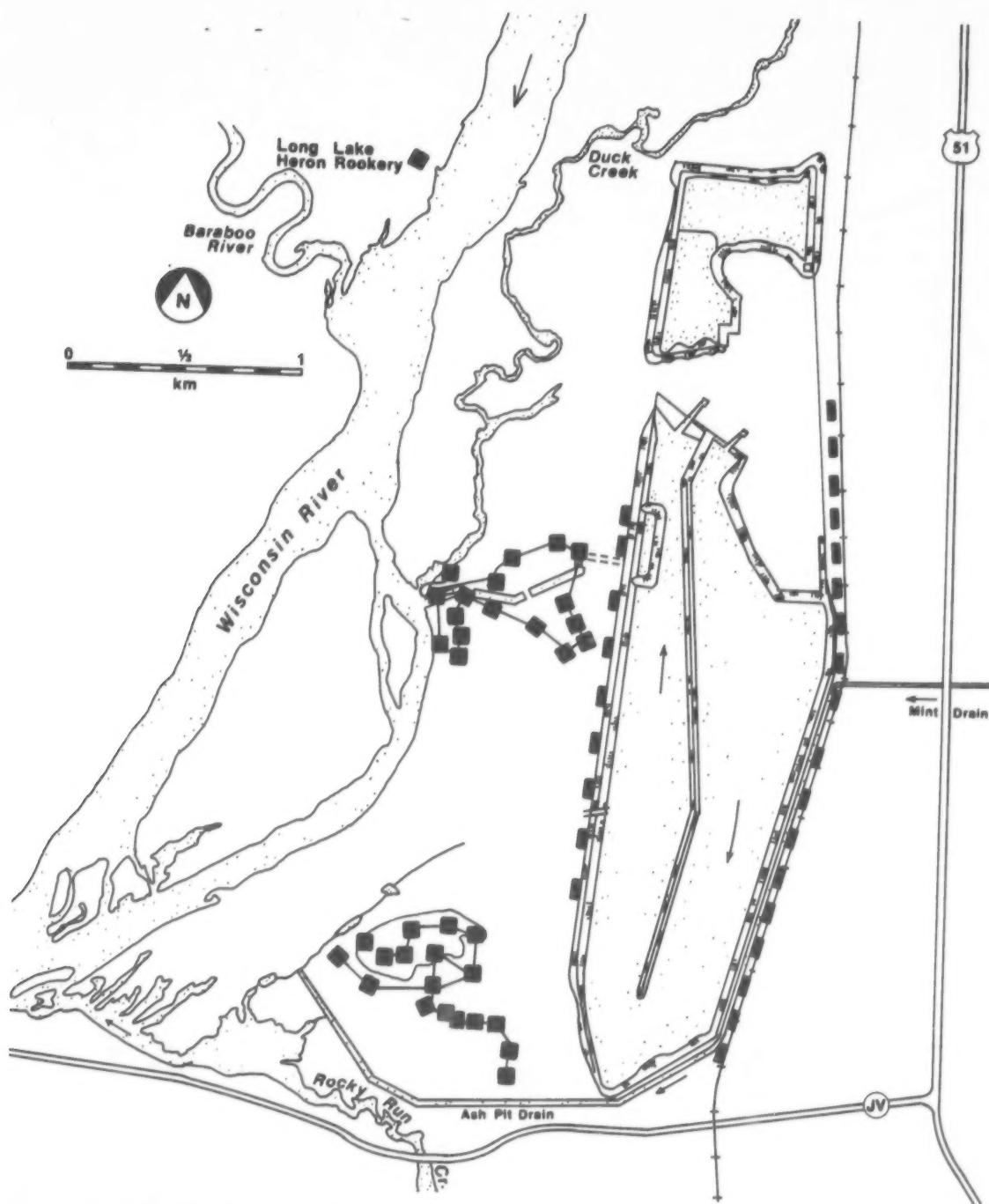


Figure 24. Bird survey transects (T1 not included).

Observation Method--

Experiments determined the most accurate and precise technique for surveying the stations. In this method each station was observed for 3 min. Starting at one edge of the station, the observer slowly walked through the station to the other edge in the 3 min. allowed, recording all birds seen within the station. This method gave all areas within the station an equal chance of being observed.

To eliminate diurnal variability, each observer surveyed only 1 transect on each observation date, and on all occasions sunrise was the starting time. To minimize the effect of variation among observers as much as possible, the observers rotated through the different transects. Although the rotation was not entirely systematic, each observer sampled each of the 5 transects at least once.

The field workers were well-trained in identification of birds by sight and sound. However, since pretests revealed variation in the observers' abilities to detect and identify the calls, birds were identified by sight only.

A set of six guidelines was used in walking a transect to help make the observations consistent: (1) Birds seen flying into a station but not seen again during the 3 min. period were counted; (2) birds flying over or through the station at treetop level or less were counted; (3) birds flushed from the station as the observers entered the station were counted; (4) birds flushed as the observer left the station after the 3 min. period were not counted; (5) difficult identifications could be made after the 3 min. period; (6) new species for the transect seen between stations were recorded, but not in the station data.

The observer recorded the observations on cards by writing the species sighted and the number of observed birds at each station. Later the data were punched on 80-column computer cards and then verified.

Field Observers--

The field observations were collected by experienced ornithology field workers. Two of the field workers, W.W. Jones and M.J. Jaeger, were paid personnel, who observed during the whole period (1973-76). When the project started (1973) M.J. Jaeger had 5 yr of ornithology observation experience. Approximately 35% of all the observations were done by them.

The rest of the observers were volunteers who had at least one class in ornithology at the University of Wisconsin-Madison. These volunteers were tested by the above investigators to insure the quality of the observations. Thirteen volunteers took part in the survey and they stayed on the project for 1 or more years.

When a new observer started work, he or she was introduced to the transect system by walking a transect with an experienced field worker. Both independently observed each station and their observations compared to

estimate reliability and validity. No records of these comparisons were kept and no statistical analyses were done.

Investigators--

The study was designed and supervised by W.W. Jones and D. Willard. W.W. Jones is a graduate of the University of Wisconsin-Madison, with a B.S. in Zoology and an M.S. in Water Resources Management. D. Willard at the time of the study was the principle investigator of the Columbia Impact Study at the University of Wisconsin-Madison.

Supporting Documents

Wetland birds. In: Documentation of the environmental change related to the Columbia Electric Generating Station. Institute for Environmental Studies, Reports 46, 58, 62, 69, 82, University of Wisconsin-Madison.

DATA SET C13A2: KEY TO SPECIES' NAMES AND NUMBER CODES

Data Summary

Investigators--

W.W. Jones and D.E. Willard.

Abstract--

This data set contains the name and corresponding code number for each bird species observed in the bird studies (data sets C13A1 and C13A5). The file is organized according to family names. Under each family subheading, the common name and code number for each bird species belonging to that family (and observed at the site) are listed.

Data Form--

Computer file containing 304 units with one card-image/unit.

Data Format

Field Description--

The file contains two types of cards, a family name card followed by the species name cards included for that family.

Family name card

1-3	I3	Family identification number (79-128 only) ¹⁷
6-26	A21	Family name
29-36	A7	First and last species identification numbers included for that family, separated by a comma

Species name card

40-42	I3	Species identification number (not 79-128)
45-46	A21	Species common name

Missing Data--

Not applicable.

Data Sample

The sample presented here is 10 units, 1 to 10, of the 336 units included in the complete data set C13A2.

123456789012345678901234567890123456789012345678901234567

79	PHALACROCORACIDAE	001,001	1	DOUBLE-CR CORMORANT
80	PODICIPEDIDAE	003,006	3	HORNED GREBE
			6	PIED-BILLED GREBE
81	GAUVIDAE	007,011	7	COMMON LOON
			11	RED-THROATED LOON
82	STERCORARIIDAE	037,037	37	PARASITIC JAEGER

DATA SET C13A3: VEGETATION AND DISTURBANCE CHARACTERISTICS OF THE BIRD SURVEY OBSERVATION STATIONS

Data Summary

Investigators--

W.W. Jones and D.E. Willard.

Abstract--

This data set contains records of a survey undertaken to determine the major types of vegetation cover in each of the bird observation stations (data set C13A1). This information is based on the maps (data set C13A4) drawn during the summer of 1973. Changes due to physical disturbance which occurred in some of the stations were evaluated and recorded in fall 1974.

Dates of Research--

1973-74.

¹⁷ The identification numbers from 79-128 were assigned to family names. The other numbers were used for species identification.

Data Form--

Computer file containing 88 units with one card-image/unit.

Data Format

Field Description--

<u>Color</u>	<u>Format</u>	<u>Description</u>
1	I1	Transect number
2-3	I2	Station number
5	I1	Major class vegetation: 1=open water, 2=emergent vegetation, 3=sedge meadow, 4=shrub carr, 5=southern wet forest, 6=southern wet mesic forest, 7=southern dry mesic forest, southern dry forest, 8=sand barrens, 9=old field
7	I1	Secondary station vegetation (the same categories as in major vegetation): 0=no secondary station vegetation
9	I1	Physical disturbance: 1=cleared, 2=cooling lake, 3=transmission line, 4=structure, 0=no disturbance
11-12	I2	Month the disturbance started
13-14	I2	Year the disturbance started

DATA SAMPLE

The sample presented here is 24 units, 61 to 84, of the 88 units included in data set C13A3.

1234567890123456789012345

409 4 3 9 9999
410 3 0 2 0676
411 3 0 2 0676
412 3 0 2 0676
413 3 0 2 0576
414 3 0 2 0476
415 3 1 2 0476
416 3 1 2 0476
417 4 3 2 0675
418 3 0 2 0476
501 7 0 3 0976
502 9 5 3 0676
503 9 6 3 0876
504 4/3 3 0876
505 7 2 3 0976
506 4 3 9 9999
507 9 0 9 9999
508 4 3 3 0976
509 7 0 3 0876
510 9 0 3 0876
511 4 3 3 0876
512 4 3 3 0876
513 6 4 3 0876
514 4 3 3 0976

Quality Assurance

Objectives--

The objective of the study was to identify the types of vegetation present in the areas in the bird study. Since habitat plays an important role in determining species type and diversity of the bird population, identification of the vegetation at the survey stations was essential.

Sampling Sites--

Same as data set C13A1.

Vegetation Communities--

The vegetation types observed at the survey stations were highly diverse. For purposes of simplification, the vegetation types were classified into one or a combination of nine communities, as described by Curtis (1971):

- (1) Open water.
- (2) Emergent aquatic. Water table above soil surface during most of the growing season.
- (3) Shallow water marsh and sedge meadow. Water is at or slightly above the soil surface during most of the growing season. Sedges seem to be the dominant plant in the shallow water marshes on the Columbia site, hence the reason for combining the two into one category. References to sedge meadow in this report will refer to this combination.
- (4) Shrub carr. No mature trees; community dominated by shrubs. Willows (*Salix sp.*) and dogwoods (*Cornus sp.*) are the dominant shrubs on the Columbia site.
- (5) Southern wet forest. Communities of wet, lowland sites. Cottonwood and willow dominate, oaks rarely dominate.
- (6) Southern wet-mesic forest. Communities of wet, lowland sites; oaks rarely dominate. Silver maple, American elm, or ash dominate although river birch is also widespread on the site due to the influence of the Wisconsin River.
- (7) Southern dry forest and southern dry-mesic forest. Communities of dry, upland sites; oaks (for example, black oak, red oak, and white oak) and basswood usually dominate. These two communities are combined into one category because they usually appear together on the Columbia site.

- (8) Sand barrens. Inland communities of sand plains; open communities with often < 50% coverage in ground layer. Young red and black oaks are invading these areas at the site.
- (9) Old field. This is not a natural community, but one that exists due to the activities of man. At the Columbia site, these areas were once grazed or cultivated but have not been disturbed for many years. As a result some prairie species have invaded, such as big and little bluestem, and triple-lawn grasses.

Classification procedure--Each station was first mapped by a field worker. The field worker walked along the edges and the middle of each site, estimating the location of major tree canopies and the major vegetation communities. The range finder was used. From those maps the area covered by each vegetation type was estimated, and the major vegetation communities were recorded. Vegetation was classified into one of the communities according to Curtis' (1971) categorization. Physical disturbances also were identified and recorded.

Investigators--

Same as data set C13A1.

Supporting Documents

Same as data set C13A1.

DATA SET C13A4: VEGETATION COVER MAPS OF THE BIRD SURVEY OBSERVATION STATIONS (1973-74)

Data Summary

Investigators--

W.W. Jones and D.E. Willard.

Abstract--

This data set contains maps illustrating the amount and types of vegetation cover in each of the bird observation stations. The initial determination of the vegetation cover was made during the summer of 1973. The changes which occurred in some of the stations were evaluated in fall 1974 and were drawn on the maps.

Experimental Method--

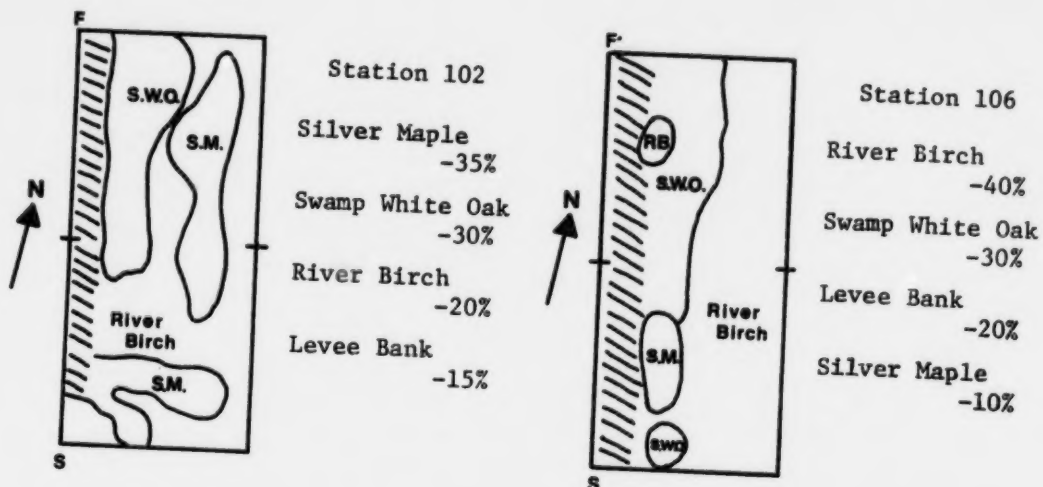
Each station was mapped by a field worker who walked along the edges and the middle of each site estimating the location of the major tree canopy and the major vegetation communities. No range finder was used.

Data Form--

This data set includes 88 maps.

Data Sample

The sample presented here is 2 maps out of 88 maps included in data set C13A4.



DATA SET C13A5: SPECIES OBSERVED ON THE COLUMBIA GENERATING STATION SITE 1972-76

Data Summary

Investigators--

W.W. Jones and D.E. Willard.

Abstract--

This data set contains records of the bird species observed at the Columbia Generating Station site during each of the years 1972-76. Every species observed either accidentally or during the course of the transect survey at the Columbia site (data set C13A1) was recorded, and a list of all species observed in each year was made. Data set C13A2 identifies the code of the bird species.

Data Form--

Computer file containing 805 units with one card-image/unit.

Data Format

Field Description--

<u>Column</u>	<u>Format</u>	<u>Description</u>
1-3	I3	Family identification number (see data set C13A2)
5-7	I3	Species identification number (see data set C13A2)
9	I1	Sighted in 1972; 1=yes, 0=no
11	I1	Sighted in 1973; 1=yes, 0=no
13	I1	Sighted in 1974; 1=yes, 0=no
15	I1	Sighted in 1975; 1=yes, 0=no
17	I1	Sighted in 1976; 1=yes, 0=no

Data Sample

This sample presents 8 units, 1 to 8, out of 197 units included in data set C13A5.

123456789012345678901234567890

079 001 0 0 0 1 0
080 003 0 0 0 1 1
080 006 1 1 1 1 1
081 007 0 0 1 1 1
083 051 0 1 1 1 0
083 054 0 1 0 0 0
083 060 0 1 1 0 0
083 077 1 1 1 1 0

Quality Assurance

Objectives--

The objective of the data set was to document qualitative changes in the composition of bird species present at the Columbia site during the 4-yr period.

Sampling Site--

The Columbia site encompasses 2,700 acres of land characterized by diverse vegetation communities. Approximately 1,100 acres were affected directly by construction of the generating station. These include a 500-acre cooling lake, 70-acre ash basin, coal-handling areas, various roads, soil piles, and other facilities. (For a description of the survey site, including the transect system, see data set C13A1).

Observation Procedure--

Each bird species observed on site 02 in the course of the transect survey (data set C13A1) was recorded.

Observers--

Same as data set C13A1.

Investigators--

Same as data set C13A1.

DATA SET C13B1: WATERFOWL ON THE COOLING LAKE OF THE COLUMBIA GENERATING STATION (1975-76)

Data Summary

Investigators--

W.W. Jones and D.E. Willard.

Abstract--

This data set contains records of a survey of the cooling lake conducted from 1975-76 to determine the impact of the Columbia Generating Station on waterfowl population. The species and number of waterfowl observed during four observations in each of the two spring migration peaks were recorded. For organizational purposes the cooling lake was divided into four zones, and the data were collected and recorded separately for each zone.

Dates of Research--

March-April 1975; March-April 1976.

Data Form--

Computer file containing 23 units with 4 card-images/unit.

Data Format

Field Description--

Card #1

<u>Column</u>	<u>Format</u>	<u>Description</u>
1-21	A21	Bird species common name
23-24	I2	Species number (numbered and listed alphabetically)
26-31	I6	Date of first 1975 observation
33-36	I4	Species count in zone 1
38-41	I4	Species count in zone 2
43-46	I4	Species count in zone 3
48-51	I4	Species count in zone 4
53-58	I6	Date of second 1975 observation

60-63	I4	Species count in zone 1
65-68	I4	Species count in zone 2
70-73	I4	Species count in zone 3
75-78	I4	Species count in zone 4
80	I1	Image sequence, 1 for card #1

Card #2

<u>Column</u>	<u>Format</u>	<u>Description</u>
23-24	I2	Species number
26-31	I6	Date of third 1975 observation
33-36	I4	Species count in zone 1
38-41	I4	Species count in zone 2
43-46	I4	Species count in zone 3
48-51	I4	Species count in zone 4
53-58	I6	Date of fourth 1975 observation
60-63	I4	Species count in zone 1
65-68	I4	Species count in zone 2
70-73	I4	Species count in zone 3
75-78	I4	Species count in zone 4
80	I4	Image sequence, 2 for card #2

Card #3

<u>Column</u>	<u>Format</u>	<u>Description</u>
23-24	I2	Species number
26-31	I6	Date of first 1976 observation
33-36	I4	Species count in zone 1
38-41	I4	Species count in zone 2
43-46	I4	Species count in zone 3
48-51	I4	Species count in zone 4
53-58	I6	Date of second 1976 observation
60-63	I4	Species count in zone 1
65-68	I4	Species count in zone 2
70-73	I4	Species count in zone 3
75-78	I4	Species count in zone 4
80	I1	Image sequence, 3 for card #3

Missing Data--

Not applicable.

Data Sample

The sample presented here is 4 units, 1 to 4, of 24 units included in data set C13B1.

1234567890123456789012345678901234567890123456789012345678901234567890

AMERICAN MERGANSER	01 040975	5	35	8	14	041675	5	4	2	14	1
	01 042275	0	8	0	0	050775	0	0	0	0	2
	01 030976	0	0	0	0	032476	0	2	0	0	3
	01 033076	3	0	0	0	040676	0	3	0	0	4
AMERICAN WIDGEON	02 040975	0	0	0	0	041675	0	0	0	0	1
	02 042275	0	0	0	0	050775	0	0	0	0	2
	02 030976	0	0	0	0	032476	12	0	0	0	3
	02 033076	0	0	0	0	040676	0	2	0	0	4
BLACK TERN	03 040975	0	0	0	0	041676	0	0	0	0	1
	03 042275	0	0	0	0	050775	0	0	3	0	2
	03 030976	0	0	0	0	032476	0	0	0	0	3
	03 033076	0	0	0	0	040676	0	0	0	0	4
BLUE-WING TEAL	04 040975	0	5	8	10	041675	0	12	2	2	1
	04 042275	0	0	0	0	050775	0	0	0	0	2
	04 030976	0	0	0	0	032476	3	0	0	0	3
	04 033076	0	0	0	0	040676	2	0	0	0	4

Quality Assurance

Objectives--

The goal of the waterfowl study was to determine the impact of the cooling lake on the waterfowl population at the Columbia site. Observations were made during the peaks of the spring migration in 1975 and 1976. The census is an absolute count of all species on the lake.

Sampling Sites--

The waterfowl study was carried out on the cooling lake of the Columbia Generating Station. The cooling lake, built on 192 ha of wetland, is approximately 2,800 m at its longest point and 850 m at its widest point, and 1.9-2.4 m deep. For organizational purposes, the cooling lake was divided into four zones (Figure 25). The data were collected and recorded separately for each zone.



Figure 25. Zones of the cooling lake.

Observation Method--

The first large influx of waterfowl to descend upon the cooling lake was used as an indicator of the beginning of the spring migration. From then on, a weekly census was conducted by a single observer from the dikes surrounding the lake. The observer stopped approximately every 500 m (at assigned locations) and counted all the birds observed in each quarter using binoculars and spotting scope.

Investigator--

The study was designed and performed by W.W. Jones, a graduate of the University of Wisconsin-Madison, with a B.S. in Zoology and an M.S. in Water Resources Management. When the study began W.W. Jones had 3-yr experience in ornithology.

Supporting Documents

Same as data set C13A1.

DATA SET C13B2: NEST COUNT IN THE GREAT BLUE HERON ROOKERY LOCATED NEAR THE COLUMBIA GENERATING STATION (1974-77)

Data Summary

Investigators--

W.W. Jones and D.E. Willard.

Abstract--

This data set contains records of a 4-yr survey of the number and distributions of great blue heron nests in the Long Lake rookery. The rookery was located 1.6 km west of the Columbia Generating Station along the west bank of the Wisconsin River. To determine the effect of the generating station on the population of the rookery, the number of nests and their distribution were recorded each year after the end of the breeding season.

Dates of Research--

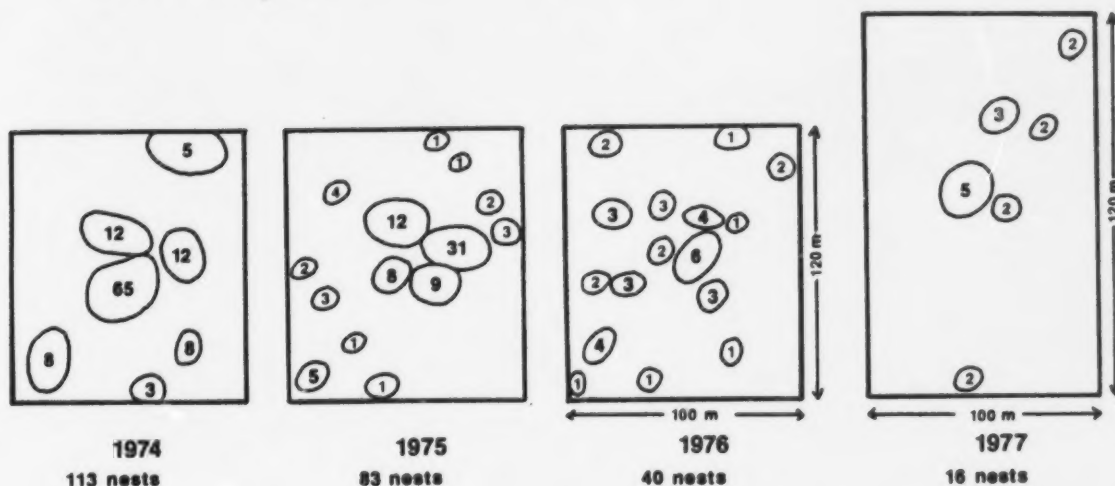
Fall 1974-fall 1977.

Data Form--

This data set includes four maps.

Data Sample

This is the complete data set C13B2.



Quality Assurance

Objectives--

This survey was designed to determine the consequence of the cooling lake on the population of nesting great blue herons in the Long Lake rookery. Great blue herons are likely to return to the same nesting site for many successive years (Pearson 1936) unless physical changes occur in the site or feeding grounds. Since very few physical changes occurred in the nesting site, most of the decrease in the nesting bird population can be attributed to the removal of 500 acres of marsh, part of the feeding grounds of the heron, which was occupied by the cooling lake.

Rookery Location--

The Great blue heron rookery was located near Long Lake approximately 1 mile west of the Columbia Generating Station. The rookery was situated in a dense stand of southern wet forest dominated by silver maple (*Acer saccharinum*) and American elm (*Ulmus americana*). The rookery measured 100 by 120 m. In 1977 a few nests were discovered outside the above boundaries.

Observation Method--

Each fall (after the leaves had fallen) the nests located in the rookery were counted and mapped. Only those nests in usable condition were included in the count. Nest counts were judged to be an adequate census

method because herons generally rebuild those nests remaining from the previous season. Nests not rebuilt are in bad shape by the fall and thus were not counted. Staff avoided entering the rookery during the period of active nesting since their presence would cause a great disturbance among the birds. No systematic procedure for counting and mapping was developed, and the mapping was based on rough estimates of distances.

Investigator--

Same as data set C13B1.

Supporting Documents

Same as data set C13A1.

DATA SET C13C1: RELATIONSHIP OF WETLAND BIRDS TO WETLAND SUBSTRATE: THE BIRD DATA (1975-78)

Data Summary

Investigators--

M.J. Jaeger.

Abstract--

A survey of the distribution of breeding passerine birds in relation to vegetation and water-regime characteristics was performed during the springs of 1975, 1976, and 1978. The survey was conducted in an area of 36 ha on the west side of the cooling lake of the Columbia Generating Station. This site is bounded by the north knoll, the west dike, the river floodplain, and more wetlands. This data set contains the bird observations of the study. The observations include the number of individuals/species observed in each of the plots. The substrate data are reported in data set C13C2.

Dates of Research--

22 May to 2 June 1975, 25 May to 2 June 1976, and 28 May to 9 June 1978.

Data Form--

Computer file containing 143 units with three card-images/unit.

Data FormatField Description--Card #1

<u>Column</u>	<u>Format</u>	<u>Description</u>
1-2	I2	Transect number
3-4	I2	Station identification number
		Pied-billed grebe count in
6	I1	1975
8	I1	1976
10	I1	1978
		American bittern count in
12-17	3I2	1975, 1976, 1978 respectively
		Least bittern count in
19-24	3I2	1975, 1976, 1978 respectively
		Mallard count in
26-31	3I2	1975, 1976, 1978
		Blue-winged teal count in
33-38	3I2	1975, 1976, 1978
		American pigeon count in
30-45	3I2	1975, 1976, 1978
		Wood duck count in
47-52	3I2	1975, 1970, 1978
		Virginia rail count in
54-59	3I2	1975, 1976, 1978
		Sora count in
61-66	3I2	1975, 1976, 1978
		Killdeer count in
68-73	3I2	1975, 1976, 1978
80	I1	1 for image card #1

Card #2

<u>Column</u>	<u>Format</u>	<u>Description</u>
1-2	I2	Transect system
3-4	I2	Station identification number
		Black tern count in
5-10	3I2	1975, 1976, 1978
		Yellow-billed cuckoo count in
12-17	3I2	1975, 1976, 1978
		Ruby-throated hummingbird count in
19-24	3I2	1975, 1976, 1978
		Crested flycatcher count in
26-31	3I2	1975, 1976, 1978
		Willow flycatcher count in
33-38	3I2	1975, 1976, 1978
		Tree swallow count in

40-52	3I2	1975, 1976, 1978
		Short-billed marsh wren count in
55-59	3I2	1975, 1976, 1978
		Catbird count in
62-66	3I2	1975, 1976, 1978
		Yellow warbler count in
69-73	3I2	1975, 1976, 1978
80	I1	2 for card #2

Card #3

<u>Column</u>	<u>Format</u>	<u>Description</u>
1-2	I2	Transect system
3-4	I2	Station identification number
		Common yellowthroat count in
6-10	3I2	1975, 1976, 1978
		Redwinged blackbird count in
13-17	3I2	1975, 1976, 1978
		Grackle count in
20-24	3I2	1975, 1976, 1978
		Yellowheaded blackbird count in
27-31	3I2	1975, 1976, 1978
		Brownheaded cowbird count in
34-38	3I2	1975, 1976, 1978
		American goldfinch count in
41-45	3I2	1975, 1976, 1978
		Swamp sparrow count in
48-42	3I2	1975, 1976, 1978
		Song sparrow count in
55-59	3I2	1975, 1976, 1978
80	I1	3 for image card #3

Missing Data--

Missing data are indicated by 99.

1234567890123456789012345678901234567890123456789012345678901234567890

Quality Assurance

Objectives--

The study was designed to find the relationship between the distribution and abundance of marsh birds and environmental factors such as vegetation and water depth. Comparison of the distribution patterns of wetland bird species with the structural and vegetative characteristics in the area was intended to broaden understanding of how changes in the biotic and abiotic environment alters nesting bird populations. The study was an integral part of, and carried on simultaneously with, a study of the vegetation of wetland communities (Wetland Ecology-Plants).

Sampling Sites--

The survey of the breeding-bird community was started in spring 1975 in a portion of the wetlands bordering the west side of the cooling lake. This site, encompassing approximately 30 ha, was bounded by the north knoll, the south knoll, the west dike, and the river floodplain (Figure 26). Within the 30 ha survey site, 119 circular plots were surveyed for bird populations. The bird survey plots had a radius of 20 m and an area of 0.125 ha. The centers were placed on an existing staked 50 by 50 m grid pattern that covers that section of the wetland used for vegetation surveys by the Wetland Ecology--Plants Subgroup. In 1976 the number of circular plots was increased to 143. In 1978 the number of plots was increased to 199.

Observation Method--

The data on the breeding bird population were collected by two field workers during 1975 and 1978 and by three field workers during the 1976-77 seasons. The observers estimated an area with a radius of 20 m from the center flag; walking slowly toward the flag, they observed the birds in the plot for 12 min. It was estimated that during the 12-min. period all the

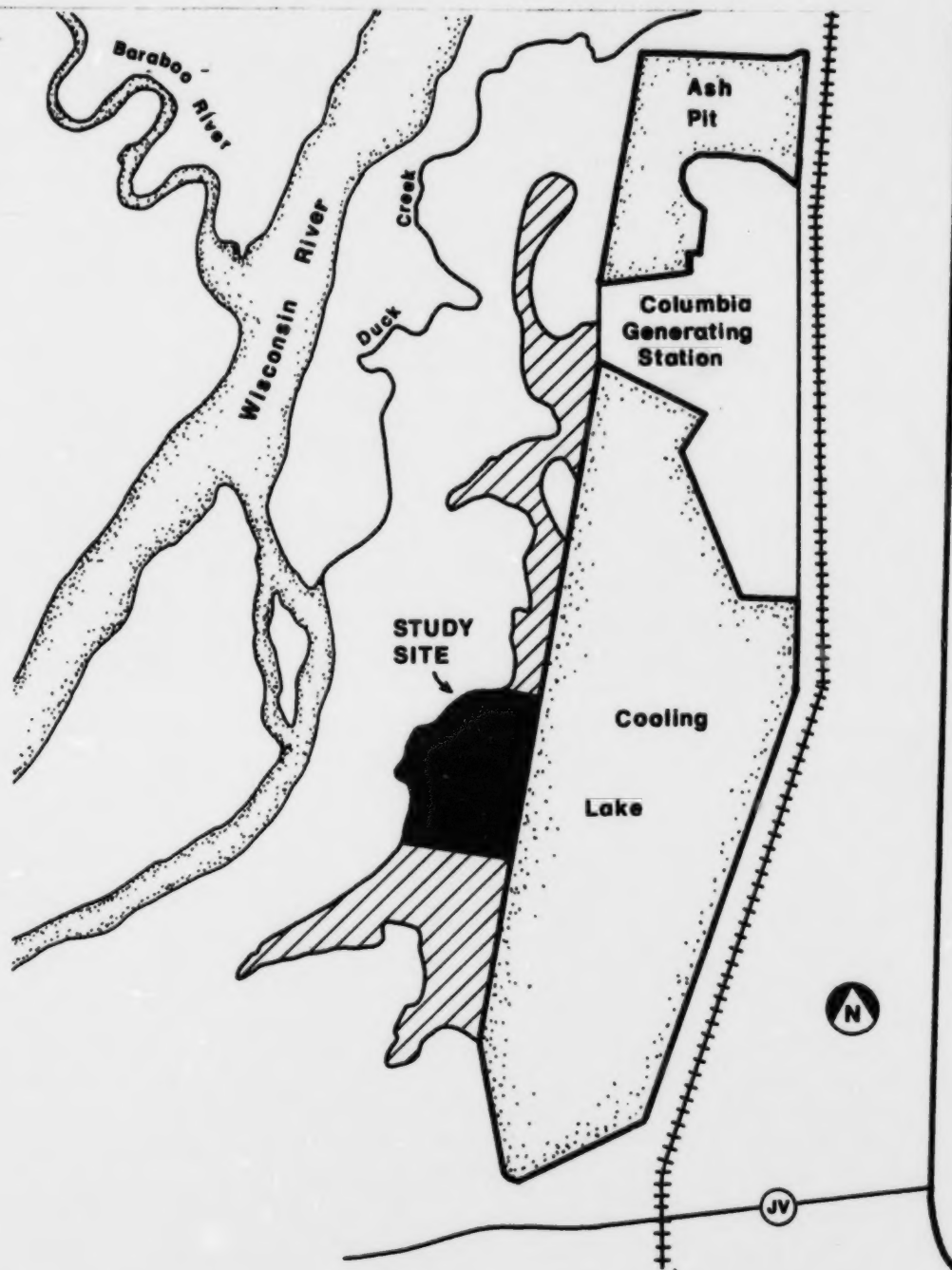


Figure 26. Columbia Generating Station and location of wetland study site adjacent to the cooling lake.

birds in the plot would be observed. Although there were no sticks or flags to mark the boundaries of the plot, the field workers estimated a 20 m radius and visualized an imaginary circle around the center flag. To eliminate diurnal variability, all the bird observations were conducted within the three hours following sunrise. The observer collected data on the number of individuals of each species present.

Observers--

During 1975 the observations were carried out by M.J. Jaeger and B. Bedford. M.J. Jaeger was a student in the University of Wisconsin working toward a B.S. degree in zoology and had 7 yr of experience in ornithology when the study started. Barbara Bedford was a graduate student at the University of Wisconsin-Madison working toward an M.S. in Land Resources Management. When the study started she had 2 yr of experience working in the wetlands at the Columbia site and 3 yr of experience at other wetland sites, doing the plant studies for the Dane County inventory for the Wisconsin Department of Natural Resources. During the 1976 and 1978 surveys, a third observer was added, S. Brick, who had approximately 6 yr of previous bird-observation experience. The observers compared observations for reliability, but, no record of these comparisons were kept and no statistical analyses were done.

Investigators--

The study was designed and supervised by M.J. Jaeger.

Supporting Documents

Jaeger, M.J. 1980. Predicting impact of an electric generating station on wetland passerine birds. U.S. Environmental Protection Agency, Cincinnati, Ohio.

Wetland ecology. In: Documentation of environmental changes related to the Columbia Electric Generating Station. Institute of Environmental Studies Reports 62, 69, 82, 92, University of Wisconsin-Madison, Madison, Wis.

DATA SET C13C2: THE RELATIONSHIP OF WETLAND BIRDS TO WETLAND SUBSTRATE:
THE SUBSTRATE DATA (1975-78)

Data Summary

Investigators--

M.J. Jaeger and B. Bedford.

Abstract--

A survey of the distribution of breeding passerine birds at the Columbia site in relation to vegetation structure and water-regime characteristics was performed during the springs of 1975, 1976, and 1978. The

study was conducted in an area of 36 ha on the west side of the cooling lake bounded by the north knoll, the west dike, the river floodplain, and more wetlands. This data set contains the substrate observations. These observations include three major measurements for each plot: percentage of ground cover, average depth (cm), and water-depth variation. These measurements were taken during each of the 3 years. During 1975 additional parameters were measured: graminoid stems (%), dead stems (%), effective height (cm), rumex-stem presence, shrub dispersion, and ground-layer dispersion.

Dates of Research--

May 1975-June 1978.

Data Form--

Computer file containing 102 units with one card-image/unit.

Data Format

Field Description--

<u>Columns</u>	<u>Format</u>	<u>Description</u>
1-4	I4	Transect plot I
6-9	F4.1	Average water depth, 1975 (cm)
11-14	F4.1	Standard deviation of water depth, 1975 (cm)
16-19	F4.1	Average water depth, 1976 (cm)
21-24	F4.1	Standard deviation of water depth, 1976 (cm)
26-29	F4.1	Average water depth, 1978 (cm)
31-34	F4.1	Standard deviation of water depth, 1978 (cm)
36-38	I3	Percentage of cover, 1975
40-42	I3	Percentage of cover, 1976
44-45	I4	Percentage of cover, 1978
48-50	I3	Percentage of graminoid stems, 1975
52-54	I3	Percentage dead stems, 1975
56-58	I3	Stem density, 1975
60-61	I2	Effective height, 1975
63	I1	Rumex-stem presence, 1975; 0=absent, 1=few, 2=moderate, 3=many
65	I1	Shrub-layer dispersion, 1975; 0=no shrub, 1=large clump, 2=large rows, 3=small clump, 4=small rows, 5=irregular
67	I1	Ground layer dispersion 1975; 1=even, 2=irregular, 3=even tussocks, 4=irregular tussocks

Missing Data--

Missing data are indicated by 999.

Data Sample

The sample presented here is 15 units, 11 to 25, of the 102 units included in the complete data set C13C2.

1234567890123456789012345678901234567890123456789012345678901234567890

2803	12.9	6.5	11.0	2.9	15.6	5.1	41	50	68	96	43	193	36	2	3	1
2804	13.7	3.0	19.1	7.8	35.9	16.4	65	45	33	99	49	170	26	2	5	1
2805	30.5	15.4	28.0	9.6	31.5	11.4	17	35	21	97	57	76	44	3	0	1
2806	28.8	3.8	36.6	5.7	56.5	6.1	59	24	0	98	46	60	22	0	0	2
2807	17.8	5.0	31.4	7.2	37.6	17.1	70	18	7	98	36	72	34	1	2	1
2808	999	999	43.1	9.5	999	999	999	9	999	999	999	999	99	9	9	9
2902	8.4	1.7	7.1	2.4	5.1	2.8	75	31	49	100	54	208	34	2	0	1
2903	9.3	2.1	16.9	9.3	22.8	8.9	87	51	13	94	55	192	8	2	0	1
2904	12.4	2.7	25.0	12.6	17.5	12.9	71	41	40	99	54	149	34	1	4	1
2905	24.0	4.8	42.8	11.2	41.3	21.4	49	9	7	98	57	63	10	0	0	1
2906	23.9	5.1	43.4	10.5	55.9	22.0	66	10	13	96	50	48	30	0	0	2
2907	29.5	5.9	44.3	4.1	53.9	7.8	24	6	14	94	68	40	20	0	1	2
2908	999	999	40.3	7.4	999	999	999	25	999	999	999	999	99	9	9	9
2909	999	999	36.2	4.7	999	999	999	30	999	999	999	999	99	9	9	9
3002	5.4	2.5	7.3	3.6	9.2	3.2	65	34	3	100	44	91	26	2	0	1

Quality Assurance

Objectives--

Same as data set C13C1.

Sampling Sites--

Same as data set C13C1.

Sampling Procedure--

Three major substrate measurements were taken in each of the study years: (1) percentage of ground-cover, (2) average water depth, and (3) water depth variation. The percentage of ground-cover was measured by running a 10-m line intercept, divided into 100 x 10-cm lengths, through each bird-sampling plot. The number of these lengths that intercepted open water and the number that intercepted vegetation cover were recorded. The average water depth was calculated by measuring the water depth every 0.5 m on the 10-m line intercept and averaging the 20 measurements. Water-depth variation was determined by calculating the standard deviation of the 20 water-depth measurements that were used to calculate the average water depth.

During 1975, seven additional parameters were measured: (4) percentage of graminoid stems, (5) percentage of dead to live stems, (6) the average number of stems in each plate, (7) a measurement of effective height, (8) a qualitative judgement on the density of dead *Rumex* flower stalks, (9) shrub dispersion, and (10) ground-layer dispersion.

To calculate the percentage of graminoid stems, 5 circles with an area of approximately 0.5 m^2 each were randomly located within each sample plot. The observers counted the number of broad-leaved stems and the number of graminoid-leaved stems and calculated the ratio of graminoid to total stems. To find the percentage of dead to live stems, the field workers counted the number of live stems and dead stems in the 5 sampling circles and calculated the ratio. The average number of stems in each plate was found by recording the total number of stems in each of the 5 sampling circles and calculating its average. At the center of each of the 5 circles a measurement of effective height (the height at which the vegetation obscured vision) was taken, and an average for the five sampling circles was calculated. A qualitative judgment on the density of dead *Rumex* flower stalks was made by assigning each plot to one of four categories: many, moderate, few, and absent. To determine shrub dispersion the observer made a qualitative measurement by assigning each plot to one of seven categories: no shrubs, small clumps, large clumps, large rows, small rows, irregular, or even. Ground-layer dispersion, also was measured qualitatively by an observer who placed each plot into one of four categories similar to the shrub-dispersion categories: even, irregular, even tussocks, or irregular tussocks. The data were collected for 59 of the bird samples in 1975 and 1978 and for 102 plots in 1976.

Observers--

Same as data set C13C1.

Investigators--

Same as data set C13C1.

Supporting Documents

Same as data set C13C1.

SECTION 14

WETLAND PLANTS

This subproject dealt with environmental changes in wetland vegetation resulting from the construction and operation of the Columbia Generating Station. The principal goals of the subproject were (1) to monitor the response of wetland vegetation to environmental changes produced by the generating station, and particularly by the cooling lake; and (2) to advance the present understanding of the processes of change taking place in wetland plant communities.

Specific objectives were: (1) to document changes in the abundance of different wetland plants in the wetland west of the cooling lake, and (2) to document the effect of changes in the thermal and water regime on plant physiology.

In relation to objective (1) two data sets are presented. Data set C14A1 (Field survey of plant species and density in the wetland plant community west of the cooling lake) describes the results of a biannual field survey (summer 1974-fall 1977) in which wetland plants were identified and counted in a defined transect system. Data set C14A2 (Photos of the plant transect system (1971-77)) includes slides of each transect taken through the different seasons, to document physical changes occurring in the transect system.

In relation to objective (2), one data set is presented. Data set C14B1 (Effect of thermal regime on shoot density, height, and condition of vegetation in the wetlands at the Columbia Generating Station site (1977-78)) presents a monthly measure of shoot conditions in different water depth and temperature regimes obtained for two selected plant species.

The investigators are Dan Willard, Associate Professor of Botany and the first director of the Columbia Power Plant Impact Study, Orle Loucks, Associate Professor of Botany and the director succeeding Dan Willard; Barbara Bedford, Research Assistant, Department of Botany; and Sarah L. Wynn, Research Assistant, Department of Civil and Environmental Engineering. The report was compiled by Saya Shacham and Hilary McLellan, Data Analysts, Water Resources Center.

DATA SET C14A1: VEGETATION CHANGES IN THE WETLAND WEST OF THE COOLING LAKE
OF THE COLUMBIA GENERATING STATION (1974-77)

Data Summary

Investigators--

B. Bedford, S. Wynn, and D. Willard.

Abstract--

A 4-yr survey (1974-77) was conducted to identify changes in species composition of the wetland plant community associated with leakage from the cooling lake into the area west of the dike. Measures of plant species densities, water depths, and water temperatures in the wetland were monitored biannually (summer and fall) in a grid system laid out on 48 ha within the sedge meadow and marsh. In addition, water clarity, water flow and direction, substrate type, and substrate temperature were recorded. This survey also provided verification for the remotely-sensed data (data set C15A3 and C15A4).

Dates of Research--

Summer 1974-fall 1977.

Data Form--

Computer file containing 4,392 units with one card-image/unit.

Data Format

Field Description--

<u>Column</u>	<u>Format</u>	<u>Description</u>
1-2	I2	Year
3-4	I2	Season: 3=summer, 4=fall
5-6	I2	Transect
7-8	I2	Station number
9	I1	Quadrat
10	I1	Water clarity: oil=1, iron=2, clear=blank
11-12	I2	Water temperature °C (approximately 6 in below surface)
13-14	I2	Water temperature at base of plant °C (usually blank)
15-16	I2	Water temperature in rooting zone
17-18	I2	Water depth to rooting zone (cm)
19-20	I2	Water depth to solid substrate (cm)
21	I1	Floating mat; 1=present, blank=absent
22	I1	Direction of water flow: 1=N, 2=NE, 3=E, 4=SE, 5=S, 6=SW, 7=W, 8=NW, blank=absent

23	I1	Water flow velocity; blank=absent, 1=slow,
24-25	I2	2=moderate, 3=swift
26	I1	Air temperature °C
27	I1	Soil substrate code: 1=mud, 2=open water,
28	I1	3=peat, 4=unconsolidated organic matter, 5=sand,
29	I1	6=upland
31-33	I3	5 means stake is a half stake
34-36	I3	5 means transect is a half transect
37-39	I3	1 means level of roots in cols. 17-18 is above
40-42	I3	water, blank otherwise
43-45	I3	Species code ¹⁸
46-48	I3	Species code
49-51	I3	Species code ¹⁸
52-54	I3	Species code
55-57	I3	Species code ¹⁸
58-60	I3	Species code
61-63	I3	Species code ¹⁸
64-66	I3	Species code
67-69	I3	Species code ¹⁸
70-72	I3	Species code
73-75	I3	Species code ¹⁸
76-78	I3	Species code
80	I1	Number of cards in set (indicated by 2 or 3)

Data Sample

The sample presented here is 15 records, 3021 to 3035 of the 4,392 units included in the complete data set C14A1.

1234567890123456789012345678901234567890123456789012345678901234567890

77 32703312121 00575 6 45 1 002010039001009050046001052001016050064025020001 2

77 32703312121 00575 6 45 1 022001030003

77 32703302221 0 13 284 5 002060046001010012016075064015022013175003

77 32703412020 02680 4 1 002015039015009065046001011002064050031001

77 32704102020 00390 25 5 002027039004009050010010016075064013065017022002 2

77 3270410 0 0 01585 5 4 009015052002016050064010020003022002036001105001

77 32704102020 00390 25 5 069001

77 32704102523 00955 28455 016050022005

77 32704102324 00020 63 4 5 009150046001052004016050064015022001036003

77 32704212020 01099 25 5 1 009065010005064007065008022010

77 32704302523 00125 63 4 5 016050064001020003036001105002066001161001

77 32704302021 01290 5 4 002005009010046001052001016075064003022001036001

77 32704302522 0 10 28455 046002016050022008030003161001

77 32705112221 00290 254 016050065001022006036005

77 32705212121 01085 512545 002004046001016050022005036001030006

¹⁸Refer to Table 36.

TABLE 36. VEGETATION SPECIES NAMES AND CODE NUMBERS

001	<i>Acorus calamus</i>	050	<i>Dryopteris thelypteris</i>
002	<i>Agropyron repens</i>	051	<i>Eleocharis acicularis</i>
003	<i>Ambrosia artemisiifolia</i>	052	<i>E. compressa</i>
004	<i>Andropogon gerardi</i>	053	<i>E. obtusa</i>
005	<i>Angelica atropurpurea</i>	054	<i>Epilobium coloratum</i>
006	<i>Apocynum sibiricum</i>	055	<i>E. angustifolium</i>
007	<i>Asclepias incarnata</i>	056	<i>Equisetum arvense</i>
008	<i>Aster junciformis</i>	057	<i>E. fluviatile</i>
009	<i>A. lucidulus</i>	058	<i>E. palustris</i>
010	<i>A. novae-angliae</i>	059	<i>Eriophorum angustifolium</i>
011	<i>A. puniceus</i>	060	<i>Erechtites hieracifolia</i>
012	<i>A. umbellatus</i>	061	<i>Eupatorium maculatum</i>
013	<i>Berula pusilla</i>	062	<i>E. perfoliatum</i>
014	<i>Betula pumila</i>	063	<i>Galium asprellum</i>
015	<i>Bidens coronata</i>	064	<i>G. boreale</i>
016	<i>B. frondosa</i>	065	<i>G. tinctorium</i>
017	<i>B. cernua</i>	066	<i>G. trifidum</i>
018	<i>Boehmeria cylindrica</i>	067	<i>C. triflorum</i>
019	<i>Bromus ciliatus</i>	068	<i>Gentiana andrewsii</i>
020	<i>B. Kalmii</i>	069	<i>G. procera</i>
021	<i>Calamagrostis canadensis</i>	070	<i>Geranium maculatum</i>
022	<i>Campanula aparinoides</i>	071	<i>Gerardia paupercula</i>
023	<i>Cardamine bulbosa</i>	072	<i>Glyceria striata</i>
024	<i>Carex aquatilis</i>	073	<i>Helenium autumnale</i>
025	<i>C. Bebbii</i>	074	<i>Helianthus grosseserratus</i>
026	<i>C. diandra</i>	075	<i>Hypericum Kalmianum</i>
027	<i>C. Emoryi</i>		<i>Impatiens capensis biflora</i>
028	<i>C. granulatis</i>	077	<i>Iris shrevei</i>
029	<i>C. hystericina</i>	078	<i>Juncus brachycephalis</i>
030	<i>C. interior</i>	079	<i>Lathyrus palustris</i>
031	<i>C. lacustris (sawgrass)</i>	080	<i>Lemna minor</i>
032	<i>C. leptalea</i>	081	<i>Leersia oryzoides</i>
033	<i>C. prairea</i>	082	<i>Liatris pycnostachya</i>
034	<i>C. rostrata</i>	083	<i>L. spicata</i>
035	<i>C. Sartwellii</i>	084	<i>Lilium michiganense</i>
036	<i>C. sterilis</i>	085	<i>Lobelia kalmii</i>
037	<i>C. stricta</i>	086	<i>L. siphilitica</i>
038	<i>C. stipata</i>	087	<i>Ludwigia palustris</i>
039	<i>C. vesicaria</i>	088	<i>Lycopus americanus</i>
040	<i>Chelone glabra</i>	089	<i>L. uniflorus</i>
041	<i>Chenopodium album</i>	090	<i>Lysimachia ciliata</i>
042	<i>Cicuta bulbifera</i>	091	<i>L. terrestris</i>
043	<i>C. maculata</i>	092	<i>L. thyrsiflora</i>
044	<i>Cirsium muticum</i>	093	<i>Lythrum alatum</i>
045	<i>Convolvulus sepium</i>	094	<i>Mentha arvensis</i>

(continued)

Table 36 (continued)

046	<i>Cornus obliqua</i>	095	<i>M. piperita</i>
047	<i>C. racemosa</i>	096	<i>M. spicata</i>
048	<i>C. stolonifera</i>	097	<i>Mimulus glabratus</i>
049	<i>Cuscuta Gronovii</i>	098	<i>Muhlenbergia glomerata</i>
099	<i>Nasturtium officinale</i>	153	<i>T. revolutum</i>
100	<i>Onoclea sensibilis</i>	154	<i>Trefolium pratense</i>
101	<i>Oxypolis rigidior</i>	155	<i>Typha latifolia</i>
102	<i>Panicum flexile</i>	156	<i>T. angustifolia</i>
103	<i>Pedicularis lanceolata</i>	157	<i>Valeriana ciliata</i>
104	<i>Phalaris arundinacea</i>	158	<i>Vicia americana</i>
105	<i>Phlox pilosa</i>	159	<i>Veronica scutellata</i>
106	<i>Pilea pumila</i>	160	<i>V. villosa</i>
107	<i>Poa compressa</i>	161	<i>Viola cucullata</i>
108	<i>Polygonum coccineum</i>	162	<i>Viola sp.</i>
109	<i>P. hydropiper</i>	163	<i>Zizia aurea</i>
110	<i>P. hydropiperoides</i>	164	<i>Alisima plantago (?)</i>
111	<i>P. lapathifolium</i>	165	<i>Veronica scutellata</i>
112	<i>P. natans</i>	166	<i>Utricularia vulgaris</i>
113	<i>P. sagittatum</i>	167	<i>Bidens cernua</i>
114	<i>Potentilla palustris</i>	168	<i>Melilotus officinalis</i>
115	<i>Pycnanthemum virginianum</i>	169	<i>Populus tremuloides</i>
116	<i>Ranunculus longirostre</i>	170	<i>Pontederia cordata</i>
117	<i>Ribes americanum</i>	171	<i>Aster simplex</i>
118	<i>Rudbeckia hirta</i>	172	<i>Carex lasiocarpa</i>
119	<i>Rumex orbiculatus</i>	173	<i>Scirpus cyperinus</i>
120	<i>R. verticillatus</i>	174	<i>Veronicastrum virginicum</i>
121	<i>Rorippa islandica</i>	175	<i>Phleum pratense</i>
122	<i>Sagittaria latifolia</i>	176	<i>Saponaria officinalis</i>
123	<i>Salix sp.</i>	177	<i>Ranunculus flabellaris</i>
124	<i>S. Bebbiana</i>	178	<i>Salix interior</i>
125	<i>S. candida</i>	179	<i>Carex tribuloides</i>
126	<i>S. nigra</i>	180	<i>Laportea canadensis</i>
127	<i>S. petiolaris</i>	181	<i>Viola sororia</i>
128	<i>Scirpus americanus</i>	182	<i>Carex haydeni</i>
129	<i>S. atrovirens</i>	183	<i>Lycopus virginicus</i>
130	<i>S. fuvialis</i>	184	<i>Epilobium leptophyllum</i>
131	<i>S. validus</i>	185	<i>Vitis vulpina</i>
132	<i>Scutellaria lateriflora</i>	186	<i>Salix discolor</i>
133	<i>S. galericulata</i>	187	<i>Viola papilionacea</i>
134	<i>Selaginella (sp.)</i>	188	<i>Acer saccharum</i>
135	<i>Senecio pauperculus</i>	189	<i>Anemone canadensis</i>
136	<i>Sium suave</i>	190	<i>Taraxacum officinale</i>
137	<i>Smilacina stellata</i>	191	<i>Carex lanuginosa</i>
138	<i>Solidaga canadensis</i>	192	<i>Rosa palustris</i>
139	<i>S. gigantea</i>	193	<i>Botrychium obliquum</i>

(continued)

Table 36 (continued)

140	<i>S. graminifolia</i>	194	<i>Equisetum hiemale</i>
141	<i>S. riddellii</i>	195	<i>Rubus hispidus</i>
142	<i>S. uliginosa</i>	196	<i>Osmunda regalis</i>
143	<i>Sorghastrum nutans</i>	197	<i>Erigeron philadelphicus</i>
144	<i>Sparganium eurycarpum</i>	198	<i>Agrostis alba</i>
145	<i>Spartina pectinata</i>	199	<i>Festuca elatior</i>
146	<i>Sphenopholis intermedia</i>	200	<i>Juncus nodosus</i>
147	<i>Spiranthes cernua</i>	201	<i>Papulus deltoides</i>
148	<i>Spiraea alba</i>	202	<i>Aster pillosus</i>
149	<i>Stachys hispida</i> (?)	203	<i>Panicum capillare</i>
150	<i>S. palustris</i>	204	<i>Poa praetensis</i>
151	<i>Stellaria longifolia</i>	205	<i>Setaria viridis</i>
152	<i>Thalictrum dasycarpum</i>	206	<i>Vaccinium angustifolium</i>
207	<i>Asclepias syriaca</i>	225	<i>Polygonum convolvulus</i>
208	<i>Galium obtusum</i>	226	<i>Acer saccharinum</i>
209	<i>Solidago altissima</i>	227	<i>Poa canadensis</i>
210	<i>Festuca ovina</i>	228	<i>Lepidium campestre</i>
211	<i>Polygonum pennsylvanicum</i>	229	<i>Triadenum virginicum</i>
212	<i>Medicago sativa</i>	230	<i>Solanum dulcamara</i>
213	<i>Trifolium repens</i>	231	<i>Penthorum sedoides</i>
214	<i>Riccia flutans</i>	232	<i>Echinochloa surgeons</i>
215	<i>Verbena stricta</i>	233	<i>Vernonia fasciculata</i>
216	<i>Cirsium vulgare</i>	234	<i>Geum aleppicum</i> var. <i>strictum</i>
217	<i>Lespedeza capitata</i>	235	<i>Marchantia</i> (liverwort) sp.
218	<i>Medicago lupulina</i>	236	<i>Carastium vulgatum</i>
219	<i>Panicum praecocius</i>	237	<i>Cenchrus</i> sp.
220	<i>Sporobolus cryptandrus</i>	238	<i>Alnus</i> sp.
221	<i>Conyza canadensis</i>	239	<i>Verbena hastata</i>
222	<i>Polygonum norvegica</i>	240	<i>Hypericum majus</i>
223	<i>Iris virginica</i>	241	<i>Agrostis scabra</i>
224	<i>Lepidium virginicum</i>		

Quality Assurance

Objectives--

The purpose of the field survey, conducted over a 5 year period, was to monitor change in wetland vegetation over time and to assess the impact of leakage from the cooling lake into surface waters through the ground water system. The survey was conducted jointly with the members of the remote sensing subproject (Section 15) who used these data to provide base-line identification of the plants in the wetlands at the Columbia site to serve as a guide to identifying the vegetation signature observed on the aerial photographs.

Sampling Site--

Prior to construction of the Columbia Generating Station and the cooling lake, 1,620 ha of sedge meadow, shallow marsh, shrub carr, and floodplain forest comprised a diverse wetland system. Construction directly destroyed more than 250 ha. Sampling was carried out in the sedge meadow--shallow marsh between the west dike and the lowland forest along the Wisconsin River (Figure 27), an area encompassing 57 ha.

Sampling Procedure--

A series of 40 transects at 50 m intervals but of varying lengths were laid out at an approximately 90° angle from the west dike (Figure 27). Permanent sampling stations were established by setting metal fence posts in place vertically at 50 m intervals along each transect, such that a 50 m grid was created, consisting of 200 sampling stations.

The area around each stake was divided into four quadrants. Field workers laid out a 0.5 m² circular quadrat at a distance of 1 m out from the stake in 2 of the 4 quadrants (determined using a random numbers table). The identity and number present for each species in the quadrat were recorded. Every other station along the transects was sampled this way.

A meter stick was used to obtain water depths to rooting zone and solid substrate at each sampling station. Water clarity, floating mat, direction and velocity of water flow, and the soil substrate type were determined by visual observation.

Air and water temperature readings were obtained with a Taylor thermometer which was not checked for calibration during the study. This instrument has an accuracy of $\pm 1^{\circ}\text{C}$.

Analytical Procedure--

The data were broken into community types and summarized as mean number of shoots/quadrant for each species. The mean was calculated by dividing the total number of shoots of a given species counted at the grid points in a given community type by the total number of quadrants sampled. Due to the clonal nature of many wetland plants, this mean tends to underestimate density. However, it does provide a measure of general trends.

Three plant community categories were selected:

- (1) *Carex lacustris* prominent, with *Carex stricta*, *Calamagrostis canadensis*, and *Sagittaria latifolia* locally abundant.
- (2) *Carex stricta* prominent; mixed with other sedges, grasses, forbs and ferns: *Carex lacustris*, *Calamagrostis canadensis*, *Spartina pectinata*, and *Sagittaria latifolia* locally abundant. Areas mapped as prominent *Calamagrostis canadensis* are pooled with this group for purposes of analysis.

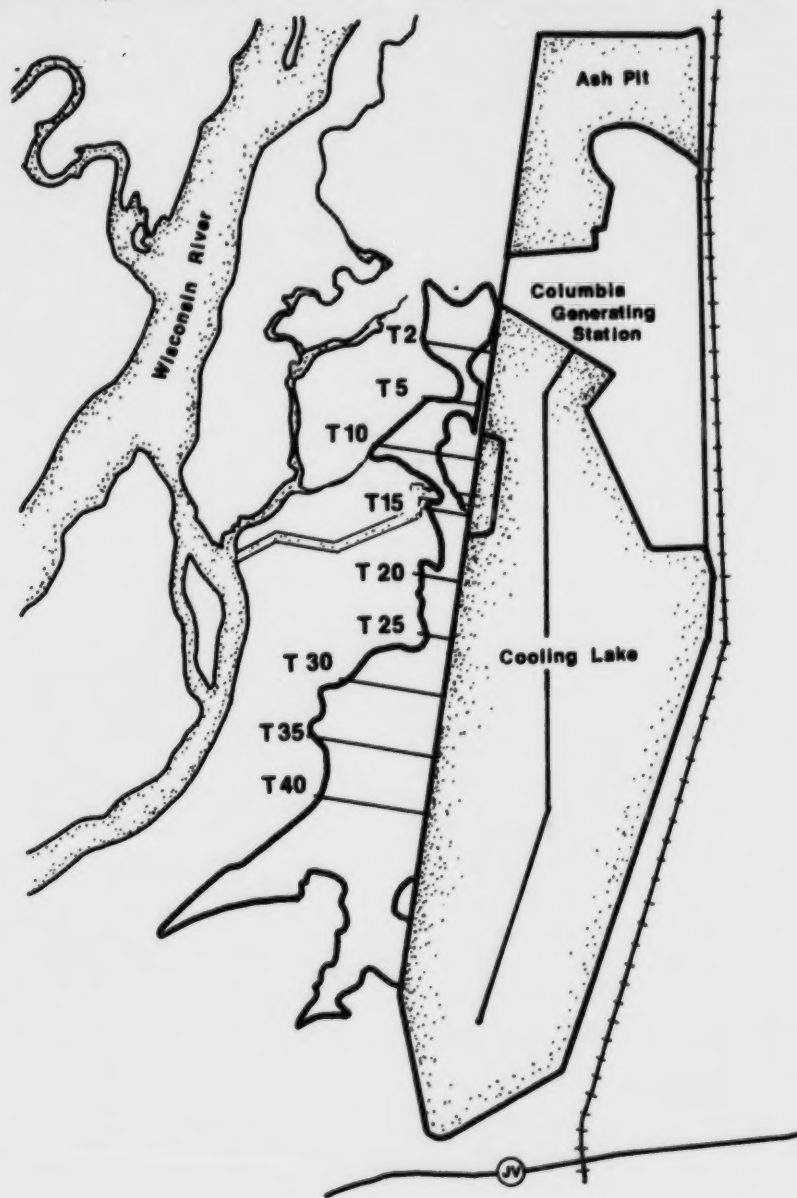


Figure 27. The sedge meadow--shallow marsh study area with every fifth transect illustrated.

- (3) Locally prominent emergent aquatics: *Typha latifolia*, *Carex lacustris*, *Sparganium eurycarpum*, *Scirpus fluviatilis*, *Acorus calamus*, *Sagittaria latifolia*, *Carex rostrata*. Areas mapped as prominent *Sparganium eurycarpum*, and open water are pooled with this group for purposes of analysis.

Investigators

The study was conducted by Sarah Wynn of the Remote Sensing Subproject and Barbara Bedford of the Wetlands Ecology-Plants Subproject. At the time of the study, Sarah Wynn was working toward a Ph.D. degree in Civil and Environmental Engineering at the University of Wisconsin-Madison under the supervision of Professor Ralph Kiefer. Barbara Bedford was working towards a Ph.D. degree in the Institute of Environmental Studies at the University of Wisconsin-Madison under the supervision of Professors Dan Willard and Orle Loucks. Field assistants helped with data collection and tabulation.

DATA SET C14A2: PHOTOS OF THE PLANT-TRANSECT SYSTEM AT THE COLUMBIA SITE (1976-77)

Data Summary

Investigators--

B. Bedford and M.J. Jaeger.

Abstract--

To document the changes in the wetland vegetation, colored slides were taken of the plant transect system at different times of the year during 1976 and 1977. The data set contains 25 slides for each of the 52 vegetation transects west of the Columbia Generating Station.

Dates of Research--

March 1976-December 1977.

Data Form--

The data consists of 1,300 35-mm slides which are stored in the Water Resources Center.

Quality Assurance

Objectives--

The purpose for obtaining the photographs was to provide a record of vegetation changes occurring in the wetland west of the Columbia Generating Station.

Sampling Site--

Same as data set C14A1.

Sampling Procedure--

The photographs were taken with a 50- or 55-mm lens with a 35-mm Nikon F single-lens reflex camera. A view straight down each transect was obtained by taking the photographs from the top of the dike. In general, photos were taken before 1100 hr to avoid strong cross- or back-lighting.

Investigators--

The study was conducted by Barbara Bedford and Michael Jaeger. At the time of the study, Barbara Bedford was working towards a Ph.D. degree in the Institute of Environmental Studies at the University of Wisconsin-Madison under the supervision of Professors Dan Willard and Orie Loucks. Michael Jaeger was working towards a M.S. degree in Zoology under the supervision of Professor Dan Willard. Field assistants helped with data collection and tabulation.

DATA SET C14B1: EFFECT OF THERMAL REGIME ON SHOOT DENSITY, HEIGHT, AND CONDITION OF VEGETATION IN THE WETLANDS AT THE COLUMBIA GENERATING STATION SITE (1977-78)

Data Summary

Investigators--

B. Bedford and O. Loucks.

Abstract--

Typha latifolia and *Carex lacustris*, two species at the Columbia site that exhibited obvious, rapid, and different responses to impact were studied. Measurements of water temperature ($^{\circ}\text{C}$), substrate temperature ($^{\circ}\text{C}$), water depth (cm), number of shoots, height (cm), and condition were used to identify sequential field responses to impact. The measurements were taken monthly from March 1977 to July 1978 in 15 0.2 m^2 quadrats at each of the five sites for *Typha* and four sites for *Carex* (a fifth site for *Carex* was added later). These measurements, coupled with quarterly analysis of below-ground storage organs for total non-structural carbohydrates, were used to ascertain physiological mechanisms regulating change at the species level.

Dates of Research--

March 1977-June 1978.

Data Form--

Computer file containing 103 units with 5 card-images/unit.

Data Format

Field Description--

Card #1

<u>Column</u>	<u>Format</u>	<u>Description</u>
1-5	A5	Genus name of emergent
7	I1	Genus code 1= <i>Typha</i> , 2= <i>Carex</i>
9-10	I2	Site (area)
12-13	I2	Month
14-15	I2	Day
16-17	I2	Year
19-22	F4.1	Average effective water depth (cm)
24-27	F4.1	Effective water depth standard deviation
29-32	F4.1	Average water depth (cm)
34-37	F4.1	Water depth standard deviation
39-42	F4.1	Surface water temperature (°F)
44-47	F4.1	Surface water temperature standard deviation
49-52	F4.1	Rooting zone temperature (°F)
54-57	F4.1	Rooting zone temperature standard deviation
59-61	I3	Total shoot count for date and site
63-64	I2	Number of height classes encountered in this record; if zero, no data cards are present
80	I2	Image sequence, 1 for card #1

Cards #2-5

1-5	A5	Genus name
7	I1	Genus code; 1= <i>Typha</i> , 2= <i>Carex</i>
9-10	I2	Site (area)
12-13	I2	Month
14-15	I2	Day
16-17	I2	Year
19-20	I2	Height class number
21-23	I3	Count of normal shoots in height class
24-26	I3	Count of shoots 80-100% normal
27-29	I3	Count of shoots 40-80% normal
31-32	I2	Height class number ¹⁹
33-35	I3	Count of normal shoots in height class
36-38	I3	Count of shoots 80-100% underaged
39-41	I3	Count of shoots 40-80% underaged
43-44	I2	Height class number ¹⁹
45-47	I3	Count of normal shoots in height class

¹⁹See Table 37.

48-50	I3	Count of shoots 80-100% normal
41-43	I3	Count of shoots 40-80% normal
45-46	I2	Height class number ¹⁹
47-49	I3	Count of normal shoots
50-52	I3	Count of shoots 80-100% normal
53-55	I3	Count of shoots 40-80% normal
80	I1	Image sequence number

TABLE 37. VEGETATION HEIGHTS AND CODE NUMBERS

Height class number	<i>Typha</i> height (cm)	<i>Carex</i> height (cm)
1	0-20	0-10
2	21-40	11-20
3	41-60	21-30
4	61-80	31-40
5	81-100	41-50
6	101-120	51-60
7	121-140	61-70
8	141-160	71-80
9	161-180	81-90
10	181-200	91-100
11	201-220	101-110
12	221-240	111-120
13	241-260	121-130
14	261-280	131-140
15	281-300	141-150
16	301-and up	151-and up

Data Sample

The sample presented here is 2 records, 14 and 15 of the 103 units included in the complete data set.

1234567890123456789012345678901234567890123456789012345678901234567890

CAREX	2	02	070277	6.9	2.7	57.6	1.6	28.5	1.4	27.6	1.4	109	9	1						
CAREX	2	02	070277	01	0	0	0	02	6	1	1	03	5	4	3	04	7	5	5	2
CAREX	2	02	070277	05	10	7	1	06	4	6	6	07	7	7	5	08	9	0	4	3
CAREX	2	02	070277	09	2	1	2	10	1	0	0	11	0	0	0	12	0	0	0	4
CAREX	2	02	070277	13	0	0	0	14	0	0	0	15	0	0	0	16	0	0	0	4
CAREX	2	02	081377	9.7	2.7	60.9	9.5	23.3	0.9	21.4	0.6	70	9	5						
CAREX	2	02	081377	01	0	0	0	02	2	0	0	03	1	0	0	04	3	0	1	1
CAREX	2	02	081377	05	5	0	4	06	10	1	5	07	8	4	2	08	10	5	3	2
CAREX	2	02	081377	09	1	1	1	10	3	0	0	11	0	0	0	12	0	0	0	3
CAREX	2	02	081377	13	0	0	0	14	0	0	0	15	0	0	0	16	0	0	0	4
																				5

Quality Assurance

Objectives--

The purpose of the study was to determine the physiological mechanisms of plants that regulate change at the species level. Two species in the wetland adjacent to the Columbia Generating Station were selected for study since they exhibited obvious, rapid, and different responses to the environmental impacts brought on by the construction and operation of the power plant.

Sampling Sites--

The sampling sites were located in the wetland west of the cooling lake which is described in data set C14A1. The sampling sites for this study lie in nearly monotypic stands of either *Typha latifolia* or *Carex lacustris*. Control sites were located east of the cooling lake where no changes in growing conditions were observed.

Sampling Procedure--

Based on observation of vegetation changes in the wetland (data set C14A1), two plant species were selected for more intensive study to document their responses to different growing conditions to which they were exposed as a result of the introduction of the cooling lake. Sawgrass sedge (*Carex lacustris*), a sensitive perennial showing rapid decrease, and cattail (*Typha latifolia*), a tolerant, hydrophytic perennial in standing water, were monitored at approximately monthly intervals from Feb. to Oct. 1977 and from March to July 1978 for changes in shoot emergence and growth patterns.

Five sites for *Typha* and four sites for *C. lacustris* were selected on the basis of observations of thermal regime and water levels during winter 1976-77. Each site selected for each plant species had different growing conditions during that winter. The sites for both species included the following growing conditions: (1) frozen ground, (2) flowing cold water, and (3) flowing warm water. For *Typha* a fourth site with flowing water and slightly elevated temperatures was studied. For *Carex lacustris*, a fourth site was added in Oct. 1977. In addition to these sites, for each species a control site was selected east of the cooling lake where no changes in growing conditions were observed.

Since the thermal conditions in the wetland are not temporally or spatially uniform, the sampling sites were distributed at various locations subject to different thermal regimes.

At each site, shoot number, height, and condition were recorded in 15 random quadrats. Quadrats were circular and measured 0.2 m^2 in area. Water depth, surface water temperature, and substrate temperature were recorded at each quadrat using the same procedure as that described for the semi-annual vegetation sampling (data set C14A1).

The physiological responses of *T. latifolia* and *C. lacustris* to changes in water and heat flows were examined using measures of below ground biomass and levels of total non-structural carbohydrates (TNC) stored in the rhizomes (Gustafson 1976, Linde et al. 1976, McIntire and Dunstan 1976, Mooney and Chu 1974). Four 0.07 m² samples were collected at each of five sites for *Typha* and at each of four sites for *C. lacustris* in Oct. 1977 and Jan. 1978. Samples were taken to the lowest depth of the rooting zone. Frozen samples of the rooting zone were obtained during the winter using a chain saw. These were returned promptly to the laboratory, thawed at room temperature, and washed to remove soil and associated plant debris. Non-frozen samples were obtained with a special corer designed for the project. These also were returned to the laboratory and washed like the other samples. All identifiable rhizomes and shoot bases remaining intact after the washing process were retained. These were wrapped in aluminum foil and submersed for several minutes in liquid N to diminish metabolic activity. All samples were stored at < 0°C for later processing.

Prior to laboratory analysis, samples were thawed at room temperature, dried for at least 48 hr in a forced-air oven at 70°C, weighed, and ground. The modified Weinmann method of Smith (1969) was used to remove nonstructural carbohydrates and analyze for total levels.

A snow and litter removal experiment was conducted in the winter of 1977-78 in order to determine the effects of exposure on over-wintering shoots of *Carex lacustris*. Fifteen 0.20 m² quadrats were randomly selected in the fall of 1977 at a control site and permanently marked with wooden stakes. All detached litter was removed from the quadrats by hand; all standing dead vegetation was clipped to an even height of 50 cm above the soil surface. Shoot number, height, and condition were recorded for each permanent quadrat and for 15 randomly selected control quadrats in the same area. Snow was removed regularly, although not necessarily immediately, from the permanent quadrats throughout the winter. Removal was done carefully by hand and with a soft brush to prevent physical damage to the shoots. Measures of shoot number, height, and condition were repeated in late April for the 15 permanent quadrats and 15 randomly selected control quadrats in the same area.

Investigators--

Same as data set C14A1.

Supporting Documents

Same as data set C14A1.

REFERENCES

- Gustafson, T.D. 1976. Production, photosynthesis, and the storage and utilization of reserves in a natural stand of *Typha latifolia* L. Ph.D. Dissertation. University of Wisconsin-Madison.

- Linde, A.F., T. Janisch, and D. Smith. 1976. Cattail: The significance of its growth, phenology and carbohydrate storage to its control and management. Tech. Bull. No. 94. Wisconsin Department of Natural Resources, Madison, Wisconsin.
- McIntire, C.L., and W.M. Dunstan. 1976. Nonstructural carbohydrates in *Spartina alterniflora* Loisel. Bot. Marina 19:93-96
- Mooney, H.A., and C. Chu. 1974. Seasonal carbon allocation in *Heteromeles arbutifolia*, a California evergreen shrub. Oecologia (Berl.) 14:295-306.
- Smith, D. 1969. Removing and analyzing total monstructural carbohydrates from plant tissue. College of Agriculture Research Report 41. University of Wisconsin-Madison.

SECTION 15

REMOTE SENSING

This subproject explored the integration of remote sensing techniques and botanical ground sampling methods to detect, quantify and assess environmental change in wetland vegetation resulting from the construction and operation of the Columbia Generating Station. The principal goals of the subproject were: (1) to develop and refine interactive computer data analysis techniques for digital analyses of photographic data and (2) to use community classification by botanic and remote sensing methods to monitor and evaluate change in the composition, size, and location of plant communities in the wetlands.

Specific objectives were: (1) To identify and evaluate change in the wetland vegetation at the Columbia site through the integrated use of remote sensing techniques and botanical ground sampling; (2) to experiment with interactive computer data analysis techniques for digital analysis of aerial photographic data in order to develop and refine the computer techniques; (3) to produce interpretive maps of on-site vegetation using human and computer interpretation techniques.

In relation to objective (1), four data sets are presented. Two of these data sets, C14A1 and C15A1, present the botanical ground sampling data. Another data set, C15A2, presents the aerial photographic documentation of the site throughout the study period. The fourth data set, C15A3, presents computer interpreted records derived from the photographs that were used in conjunction with the field sampling and the actual photos to detect, quantify and assess environmental change in the wetland vegetation near the Columbia site.

Data set C14A1 (Vegetation changes in the wetland west of the cooling lake of the Columbia Generating Station (1974-77)) presents the results of a field study that provided a basis for identifying the community patterns of vegetation resources in the aerial photographs. This survey was conducted jointly by the Remote Sensing and Wetlands Ecology Plants Subprojects. This data is documented in Section 14, Wetlands Ecology Plants.

Data set C15A1 (Survey of vegetation counts and cover west of the cooling lake at the Columbia Generating Station (1976)) presents the results of a field study that provided a basis for determining whether vegetation community boundaries were as sharply delineated on the ground as they appeared to be in the airphotos.

Data set C15A2 (Aerial photographs of the wetland area west of the cooling lake and related sites (1972-77)) contains color and color infrared aerial photographs of the Columbia Generating Station, Hook Lake, Mud Lake, and the Waubesa and Waunakee marshes acquired at all seasons and from several altitudes (2,500, 5,000, and 10,000 ft).

Data set C15A3 (Scanned data from selected color and color infrared aerial photographs of the Columbia Generating Station Site (1974-77)) presents selected photographic images from data set C15B1 that were converted to digital arrays with a scanning microdensitometer in order to identify and evaluate change in wetland vegetation with the assistance of computer techniques.

In relation to objective (2), two data sets are presented.

Data set C15B1 (Image processing software for digitizing color and color infrared photographs (RS*FS)) documents 29 programs developed at the University of Wisconsin-Madison to provide the basis for computer-assisted analysis of remotely-sensed data.

Data set C15B2 (Scanned data from selected color and color infrared aerial photographs of the Columbia Generating Station Site, Hook Lake, Waubesa and Waunakee Marshes, and Mud Lake (1976-77)) presents data from data set C15B1 converted to digital arrays in order to test the effectiveness of the computer analysis techniques in identifying wetland vegetation resources.

In relation to objective (3), maps were produced by the investigators and are presented in other published reports.

The investigators of this group are Ralph Kiefer, Professor of Civil and Environmental Engineering; Frank Scarpace, Assistant Professor of Civil and Environmental Engineering; Lawrence T. Fisher, Program Coordinator, Environmental Monitoring and Data Acquisition; Sarah L. Wynn, Research Assistant, Department of Civil and Environmental Engineering; and Warren Buchanan, Research Assistant, Department of Civil and Environmental Engineering. The report was compiled by Hilary McLellan, Data Analyst, Water Resources Center.

DATA SET C15A1: SURVEY OF VEGETATION COUNTS AND COVER WEST OF THE COOLING LAKE AT THE COLUMBIA GENERATING STATION (1976)

Data Summary

Investigators--

S. Wynn and R. Kiefer.

Abstract--

This data set contains the results of a 5-month survey of the wetlands west of the cooling lake. Between July and Nov. 1976, 482 field stations were surveyed for vegetation type, soil type, water-flow directions, turbidity, and water depth. In addition, boundaries between adjacent areas were identified as either definite or indistinct. These records provided a guide to identifying the vegetation cover patterns observed in the remotely sensed data.

Dates of Research--

July through November 1976.

Data Form--

Computer file containing 2,580 units with one card-image/unit and 1,200 photographic slides.

Data Format

Field Description--

File 1

<u>Column</u>	<u>Format</u>	<u>Description</u>
1-2	I2	Year
3-4	I2	Month
5-6	I2	Day
7-8	I2	Sample area number (1-65)
9-10	I2	Quadrat number (1-65)
11	I1	Flow direction; 1=N, 2=NE, 3=E, 4=SE, 5=S, 6=SW, 7=W, 8=NW
12	I1	Velocity; 0=still, 1=slow, 2=moderate, 3=fast
13	I1	Turbidity; 0=clear, 1=slight, 2=moderate, 3=considerable
14-15	I2	Water depths to substrate=plant root mass (cm)
16-17	I2	Water depths to solid substrate
18	I1	Soil type
19	Ix	
21-23	I3	Species identifier ²⁰
24-26	I3	Species count (total number)
27	Ix	
28-30	I3	Species identifier ²⁰
31-33	I3	Species count
34	Ix	
35-37	I3	Species identifier ²⁰

²⁰See Table 36.

38-40	I3	Species count
41	Ix	
42-44	I3	Species identifier ²⁰
45-47	I3	Species count
48	Ix	
40-51	I3	Species identifier ²⁰
52-54	I3	Species count
55	Ix	
56-58	I3	Species identifier ²⁰
59-61	I3	Species count
62	Ix	
63-65	I3	Species identifier ²⁰
66-68	I3	Species count
69	I3	
70-72	I3	Species identifier ²⁰
73-75	I3	Species count

File 2

<u>Column</u>	<u>Format</u>	<u>Description</u>
1-2	I2	Year
3-4	I2	Month
5-6	I2	Day
7-8	I2	Sample area number (1-65)
9-10	I2	Quadrat number (1-65)
11	I1	Flow direction; 1=N, 2=NE, 3=E, 4=SE, 5=S, 6=SW, 7=W, 8=NW
12	I1	Velocity; 0=still, 1=slow, 2=moderate, 3=fast
13	I1	Turbidity; 0=clear, 1=slight, 2=moderate, 3=considerable
14-15	I2	Water depths to substrate=plant root mass (cm)
16-17	I2	Water depths to solid substrate
18	I1	Soil type
19	I1	
21-23	I3	Species identifier ²⁰
24-26	I3	Species cover (%)
27	Ix	
28-30	I3	Species identifier ²⁰
31-33	I3	Species cover
34	Ix	
35-37	I3	Species identifier ²⁰
38-40	I3	Species cover
41	Ix	
42-44	I3	Species identifier ²⁰
45-47	I3	Species cover
48	Ix	
40-51	I3	Species identifier ²⁰
52-54	I3	Species cover
55	Ix	
56-58	I3	Species identifier ²⁰

59-61	I3	Species cover
62	Ix	
63-65	I3	Species identifier ²⁰
66-68	I3	Species cover
69	I3	
70-72	I3	Species identifier ²⁰
73-75	I3	Species cover

Data Sample

The sample presented here is 15 records, 1 to 15, of the 1,350 records included in file 1 of data set C15A1.

123456789012345678901234567890123456789012345678901234567890

760727010100011664	006012
760727010200013664	006012
760727010300005104	006010 01002
760727010400214634	006011 010001
760727010500014164	002001 006010 010001
760727010600000484	002007 006003 010001 011001
760727010700005054	006011 010001
760727010800012624	006012
760727010900007124	006002 009008 034002
760727011000015164	006004 009007 010001
760727011100015713	006006 009004 010001 011001
760727011200016163	006010 010001 011001
760727011300016703	006012
760727011400014383	006012
760727011500000000	006005 009005 010001 011001

The sample presented here is 15 records, 1 to 15, of the 1,230 records included in file 2 of data set C15A1.

123456789012345678901234567890123456789012345678901234567890

760727010100011664	006017
760727010200013664	002001 006038
760727010300005104	006030 010002
760727010400214634	002001 006016 010002
760727010500014164	002001 006020 010003
760727010600000484	002005 006002 010010 011001 165001
760727010700005054	006013 010001
760727010800012624	006016 010001
760727010900007124	006009 009020
760727011000015164	006014 009025 010004
760727011100015713	006008 009030 010002 011001
760727011200016163	006012 010002 011004
760727011300016703	006006 105001
760727011400014383	006020
760727011500000000	006018 009020 010002 011002

QUALITY ASSURANCE

Quality Assurance

Objectives--

These data were collected for several reasons: (1) to test the vegetational homogeneity of areas that appeared visually homogeneous on airphotos; (2) to test whether vegetation community boundaries were as sharply delineated on the ground as they appeared to be in the airphotos; and (3) to compare vegetation community boundaries and composition between degraded areas (heavily changed due to increased water from the cooling lake) and underground areas.

Sampling Sites--

Sampling was restricted to an area between transects 18 and 40 (Figure 28). This area was subdivided into four sections which appear on the air photos. A preliminary selection of sampling sites in these four areas was made from a color infra-red photo of the study site. Subsequently, these selected areas were located in the field and a determination was made as to their suitability; 482 stations were selected for sampling.

Sampling Procedure--

The center of a particular area or patch was first determined. From this center, 20 0.25 m^2 quadrats were selected and sampled. Thirty visually dominant species were chosen for inclusion in the list of species sampled. They were selected by their commonness, height and cover (generally a combination of all three--these being the species believed to make up the tones seen in the air photos). If a sizeable patch of a species not on the list was observed within a sample quadrat, it was added to the species list.

Since an important aspect of this field study was to determine whether adjacent areas were fairly definite or indistinct, this was a factor in data collection. The boundary between two areas was visually defined and quadrats were placed randomly along either side of this line but at a consistent distance out from the line. If the boundary was clean between two areas, the quadrats along each side of the boundary closely reflected the composition of the patches of which they were a part. Ten quadrats on each side were found to be an adequate sample. Where the boundary between two communities was very difficult to distinguish visually, additional quadrats were placed parallel to the first two lines of 10 but back toward the center stake of each patch. The theory to this being that the closer to the center stake, the more homogeneous the area. Forty quadrats were the maximum used to define any one boundary. Twenty-five boundaries were sampled.

The cover data was collected with a 35-mm Nikon F single lens reflex camera with a 24-mm focal length (wide angle) lens. The camera was mounted on an 8-ft long, 2-in. diameter dowel, held directly over each quadrat sampled, and a vertical color slide was taken. A meter stick was laid on top of the vegetation in each slide so that all slides could be projected to

FIRST
LINE OF
TEXT
HERE

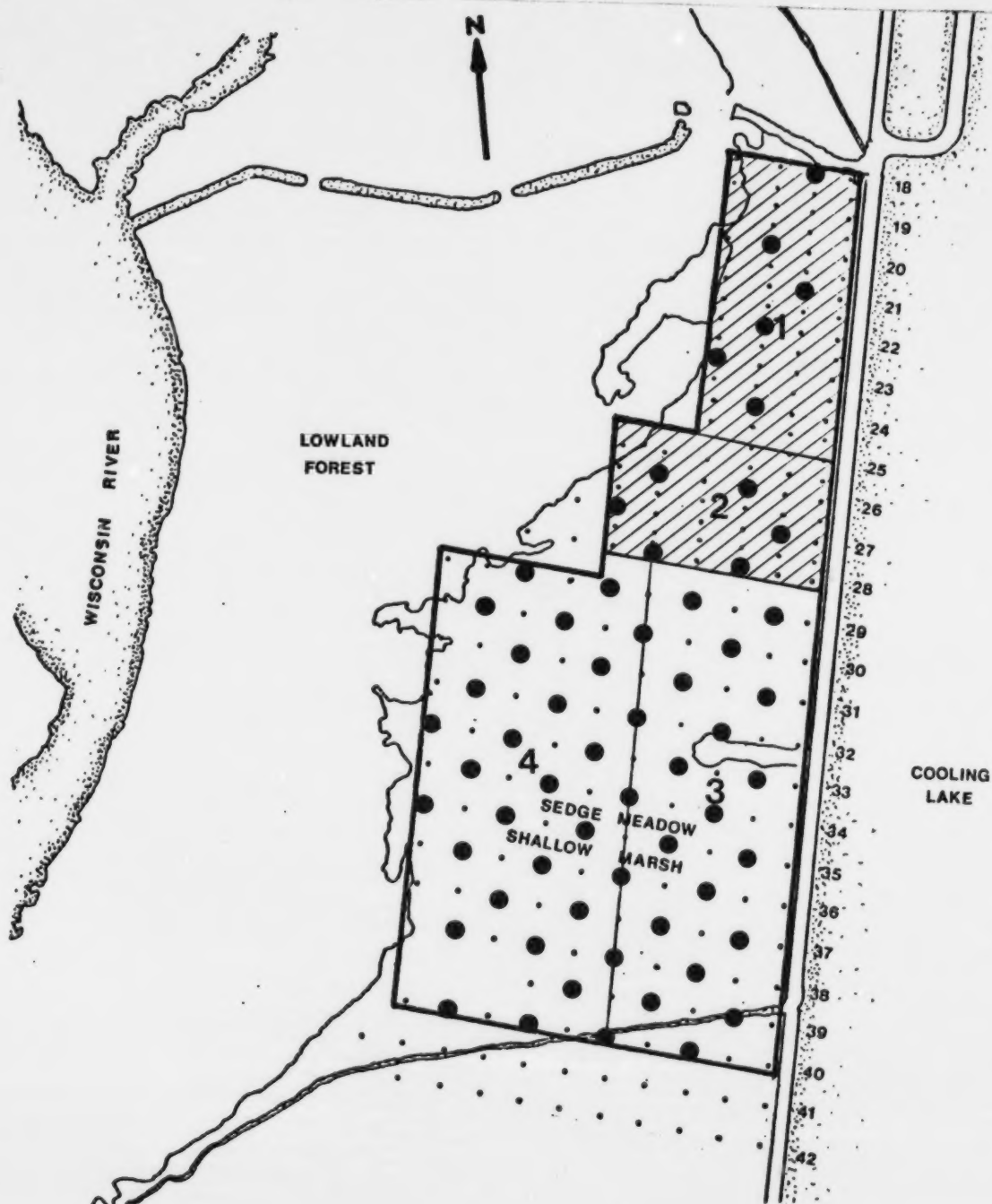


Figure 28. Remote sensing sampling stations in the wetland west of the cooling lake.

a common scale. The meter stick also was used to obtain water depth measurements.

A total of 1,200 slides were taken. The photographic slides were projected against a circular grid with 12 points marked on it, dividing the grid into sections. Readings of vegetation species cover was tabulated by this method.

Air and water temperature readings were obtained with a Taylor thermometer which was not checked for calibration during the study. This thermometer had an accuracy range of $\pm 1^{\circ}\text{C}$.

Water flow direction, velocity and turbidity were determined by visual observation.

Standardization of Data--

A meter stake was laid on top of vegetation in each slide so that all slides could be projected to a common scale.

Investigators--

All parts of the study were conducted by Sarah L. Wynn, who at the time of the study was working toward a Ph.D. degree in Civil and Environmental Engineering at the University of Wisconsin-Madison. The study was conducted under the supervision of Professor Ralph Kiefer. Field assistants with experience in botanical identification assisted in the data collection.

Supporting Documents

Buchanan, Warren. 1978. Mapping vegetation complexes with digitized color infrared film. M.S. Thesis. University of Wisconsin-Madison. 78 p.

Remote sensing. In: Documentation of environmental change related to the Columbia Electric Generating Station. Institute for Environmental Studies, Reports 62, 66, 69, 82, and 92, University of Wisconsin-Madison.

Wynn, Sarah, and Ralph Kiefer. 1977. Monitoring vegetation changes in a large impacted wetland using quantitative field and remote sensing methods. Presented at the Fourth Joint Conference on Sensing Environmental Pollutants. American Chemical Society, U.S. Environmental Protection Agency and others. November, 1977, New Orleans. Available in: Representative Papers From a Study of the Impact of Coal-Fired Power Plants on the Environment. Institute for Environmental Studies, University of Wisconsin-Madison.

Wynn, Sarah, and Ralph Kiefer. 1978. Quantitative analysis of wetland vegetation changes monitored using color and color-infrared aerial photography. Presented at the spring 1978 Annual Meeting of the American Society of Photogrammetry, Washington, D.C.

Wynn, Sarah. 1979. A comparison of data collection analysis methods used to monitor impacts over time in a severely disturbed wetland. Ph.D. Dissertation, University of Wisconsin-Madison.

DATA SET C15A2: AERIAL PHOTOGRAPHS OF THE WETLAND AREA WEST OF THE COOLING LAKE AND RELATED SITES (1972-77)

Data Summary

Investigators--

S. Wynn and R. Kiefer.

Abstract--

This data set contains color and color infrared aerial photographs of the wetlands west of the Columbia Generating Station. These photographs, acquired at all seasons and from several altitudes (2,500, 5,000, and 10,000 ft), provide a record of the vegetation changes occurring at the Columbia site. Aerial photographs of four similar wetland sites, Hook Lake, Mud Lake, and the Waubesa and Waunakee marshes, also are included.

Dates of Research--

1972-1977.

Data Form--

Color and color infrared film images, either 35-mm or 70-mm format. The total set consists of 100 photographs.

Data Format

These data are in the form of photographs. A list of the photographs included in data set C15A2 is presented in Table 38.

TABLE 38. LISTING OF REMOTE SENSING PHOTOGRAPHS IN DATA SET C15A2

Date	Film type	Scale	Source	Format/# frames
06/27/49	Black & white	1:20000	ASCS ^a	4 9"x9" frames
04/07/67	Black & white	1:15480	DOT ^b	
05/13/68	Black & white	1:20000	ASCS	3 9"x9" frames
04/04/70	Black & white	1:6000	Alster ^c	65 9"x9" frames

(continued)

Table 38 (continued)

Date	Film type	Scale	Source	Format/# frames
05/24/71 through 08/17/72 Autumn 1971	Black & white Color Infrared		Airpix ^d LL ^e	20 9"x18" frames 3 9"x9" frames 3 transparencies
04/04/71	Black & white	1:7900	DNR ^f	
04/14/71	Black & white	1:6600	DNR	
05/13/71	Black & white	1:7900	DNR	
08/04/71	Black & white	1:1200	DOT	
04/10/72	Color Infrared	1:12000 1:24000	UW ^g	35mm rolls
04/11/72	Color Infrared	1:12000 1:24000	UW	35mm rolls
05/13/72	Black & white	1:7900	DNR	15 9"x9" frames
06/04/72	Color & color IR	1:120000	NASA ^h	9"x9" transparency roll
09/27/72	Black & white IR	1:7900	DNR	11 9"x9" frames
11/13/72	Color IR		UW	35 mm rolls
03/18/72	Color		DNR	11 9"x9" frames
05/14/73	Color & color IR	1:32300	UW	2 35mm rolls color
10/12/73	Color & color IR	1:30500 1:29200 1:60900	UW	2 35mm rolls color
11/08/73	Color & color IR	1:60900	UW	35mm rolls
04/15/74	Color & color IR	1:12200 1:24400	UW	35mm rolls
04/16/74	Color & color IR	1:17000	UW	35mm rolls
05/24/74	Color	1:17000	UW	35mm rolls
06/04/74	Color	1:12200	UW	35mm rolls
06/17/74	Color IR	1:12200	UW	35mm rolls
07/31/74	Color & color IR	1:120000	NASA	9"x9" transparency rolls
08/07/74	Color IR	1:24400 1:54800	UW	35mm rolls
08/08/74	Color IR	1:24400	UW	35mm rolls
08/08/74	Color	1:54800	UW	35mm rolls
10/10/74	Color IR	1:18300 1:12200	UW	35mm rolls
10/10/74	Color	1:24400	UW	35mm rolls
11/22/74	Black & white	1:24000	DOT	4 9"x9" prints
03/19/75	Color & color IR	1:19100 1:38200	DNR	70mm rolls
03/19/75	Color	1:76400	DNR	70mm rolls
03/19/75	Color	1:76400	DNR	9"x9" prints
06/13/75	Color		DNR	10 9"x9" prints

(continued)

Table 38 (continued)

Date	Film type	Scale	Source	Format/# frames
07/10/75	Color & color IR	1:38200	DNR	70mm rolls
07/16/75	Color & color IR	1:76400	UW	70mm rolls
08/17/75	Color & color IR	1:76400		
08/26/75	Color & color IR	1:76400	UW	70mm rolls
09/25/75	Color & color IR	1:76400		
		1:38200		
10/06/75	Color & color IR	1:76400	UW	70mm rolls
11/05/75	Color & color IR	1:38200	UW	70mm rolls
		1:76400		
01/07/76	Color & color IR	1:19100	UW	70mm rolls
		1:38200		
		1:11500		
03/01/76	Color & color IR	1:38200	UW	70mm rolls
		1:19100		
		1:11500		
03/11/76	Color	Obliques	UW	flood plain slides
03/20/76	Color	Obliques	UW	35mm slides
04/01/76	Color & color IR	1:38200	UW	70mm rolls
		1:19100		
04/08/76	Color & color IR	1:38200	UW	70mm rolls
		1:19100		
		1:11500		
04/19/76	Color & color IR	1:38200	UW	70mm rolls
		1:19100		
		1:11500		
05/04/76	Color & color IR	1:38200	UW	70mm rolls
		1:19100		
		1:11500		
05/11/76	Color & color IR	1:38200	UW	70mm rolls
		1:19100		
		1:11500		
05/21/76	Color & color IR	1:38200	UW	70mm rolls
		1:19100		
		1:11500		
06/05/76	Color & color IR	1:38200	UW	70mm rolls
		1:19100		
		1:11500		
06/17/76	Color & color IR	1:38200	UW	70mm rolls
		1:19100		
		1:11500		
07/24/76	Color & color IR	1:38w00	UW	70mm rolls
		1:19100		
		1:11500		
		1:5700		

(continued)

Table 38 (continued)

Date	Film type	Scale	Source	Format/# frames
09/03/76	Color & color IR	1:38200 1:19100 1:11500	UW	70mm rolls
09/24/76	Color & color IR	1:38200 1:19100 1:11500 1:5700	UW	70mm rolls
10/26/76	Color & color IR	1:38200 1:19100 1:11500	UW	70mm rolls
02/07/77	Color & color IR	1:38200 1:19100 1:11500	UW	70mm rolls
03/01/77	Color & color IR	1:38200 1:19100 1:11500	UW	70mm rolls
04/26/77	Color & color IR	1:38200 1:19100 1:11500	UW	70mm rolls
06/25/77	Color & color IR	1:38200 1:19100 1:11500	UW	70mm rolls
07/11/77	Color & color IR	1:38200 1:19100 1:11500	UW	70mm rolls
08/77	Color & color IR	1:38200 1:19100 1:11500	UW	70mm rolls
10/77	Color & color IR	1:38200 1:19100 1:11500	UW	70mm rolls
03/23/78	Color & color IR	1:38200 1:19100 1:11500	UW	70mm rolls

^aAgricultural Stabilization and Conservation Service (USDA).

^bDepartment of Transportation, State of Wisconsin.

^cAlster & Associates, Madison, Wisconsin.

^dAIRPIX, 2610 North Laramie, Chicago, Illinois.

^eLandscapes Limited, Madison, Wisconsin (no longer in operation).

^fDepartment of Natural Resources, State of Wisconsin.

^gUniversity of Wisconsin Institute for Environmental Studies, Environmental Monitoring and Data Acquisition Group, Madison, Wisconsin.

^hNational Aeronautics and Space Administration.

Quality Assurance

Objectives--

The purpose of obtaining these photographs was to provide a record of the vegetation changes occurring in the wetland west of the Columbia Generating Station. An attempt was made to obtain aerial photographs at 7-10 day intervals during periods of rapid change in the wetlands (April 1 through June 1 and late Sept. through mid-Nov.) and at monthly intervals during the rest of the year. To the extent that an airplane was available, these objectives were carried through.

Monitoring site--

The study area was the wetlands extending between the cooling lake of the Columbia Generating Station to the east and the Wisconsin River to the west.

Film Processing--

The film was sent to Precision Photo Labs in Dayton, Ohio for processing. There was a 2-3 week time lapse between film exposure and the return of the processed film.

Before a roll of film was processed, Precision Photo Labs exposed a portion of it with accurately known amounts of light to produce a grey sensitometric step wedge on the film consisting of 21 steps. This step wedge was used as a set of standards in the measurement of dye densities by which the photographic image was analyzed for computer mapping. Approximately 75% of the rolls of film were returned with step wedges. There are no stepwedges for the 31 July 1974 and the 24 Sept. 1976 photographs.

Investigators--

Sarah Wynn was responsible for coordinating the different aspects of collecting and processing the photographs contained in this data set, although the actual collection and processing were carried out by the Wisconsin Department of Natural Resources and Precision Photo Labs respectively. At the time of the experiment she was working towards a Ph.D. degree in Civil and Environmental Engineering at the University of Wisconsin-Madison under the supervision of Professor Ralph Kiefer.

Supporting Documents

Same as data set C15A1.

DATA SET C15A3: SCANNED DATA FROM SELECTED COLOR AND COLOR INFRARED AERIAL PHOTOGRAPHS OF THE COLUMBIA GENERATING STATION SITE (1974-78)

Data Summary

Investigators--

S. Wynn and R. Kiefer.

Abstract--

This data set contains numerical readings derived from scanning 70-mm color and color infrared photographs of the wetlands west of the Columbia Generating Station that were taken between July 1974 and March 1978. Three filters were used, analyzing the three colorbands of each image separately. The scanned data in this data set were used to help monitor 34 plant species present in the wetlands and to advance the state-of-the-art in the integrated use of remote sensing techniques and botanical ground sampling methods to detect, quantify, and assess environmental change in wetlands vegetation. This data set was verified using the vegetation survey (data set C14A1).

Dates of Research--

July 1974-March 1978.

Data Form--

Computer tape; high-density 800 BPI nine-track tape.

# of files (1/filter scan)	Date	File Description	Source	Altitude (ft)	Scale	Densitometer aperture scale (μ)
3	6/4/72	Portage site (no step wedge)	NASA		1:120,000	50
3	7/31/74	Portage site (no step wedge) color	NASA		1:120,000	50
3	9/25/75	Step wedge color infrared	UW			
3	9/25/75	Portage site color infrared	UW		1:120,000	50
3	6/17/76	Step wedge color infrared	UW			50

3	6/17/76	Portage site color infrared	UW			50
3	7/24/76	Step wedge color infrared	UW	2500	1:19,100	50
3	7/24/76	Portage site color infrared	UW	2500	1:19,100	50
3	6/25/77	Step wedge color	UW			50
3	6/25/77	Portage site Color	UW	2500	1:19,100	50
3	6/25/77	Step wedge color infrared	UW	2500	1:19,100	50
3	6/25/77	Portage site color infrared	UW	2500	1:19,100	50

Access Method--

These data files are intended for use with the RS*FS programs (refer to data set C15B1). If desired, copies of the files can be prepared on 800 or 1600 BPI magnetic tape in a format convenient for users of IBM equipment. This service is available at cost; interested parties should contact Dr. F.L. Scarpace, Department of Civil and Environmental Engineering, 1235 Meteorology and Space Science Building, University of Wisconsin-Madison, 53706, (608) 263-3973/262-3491.

Data Sample

Due to the nature of these data, a meaningful sample cannot be presented. It is only through further manipulation with the RS*AP programs or similar programs that this data becomes useful for evaluation.

Objectives--

The purpose of the study (in conjunction with studies carried out by the Wetlands-Ecology Plants Group) was to advance the state-of-the-art in the integrated use of remote sensing techniques and botanical ground sampling methods to detect, quantify and assess environmental change in wetlands vegetation. The scanned data in this data set was used to help monitor 34 plant species present in the area.

Study Site--

The study area consists of the sedge meadow southwest of the Columbia Generating Station. It is bounded on the east by the cooling lake dike, between the intake channel south to 100 m south of the overflow ditch. The

site was chosen on the basis of reasonable boundaries. Outside of the selected area there are 14-ft high shrubs which did not lend themselves to this type of study. Inside the study area there are four distinct categories of vegetation--all wetlands/lowlands species.

Data Collection--

The collection of the photographs (from which this scanned data set was derived) is documented in data set C1581.

Analytical Procedure--

The analysis and recording of the data from photographs was carried out with an Optronics P-1700 Photomation Mark II scanning microdensitometer, a revolving drum-type device that measures film-dye densities and simultaneously records this information onto a 7 or 9 track computer-compatible magnetic tape. For this study, all photographs were scanned in the negative mode.

Technical specifications which are of interest:

Density range: 0-3D (operator selected) measures ergs/cm^2

Density resolution: 3/256

Density repeatability: 3/128

Positional accuracy in the x and y axis: $\pm 2 \mu\text{m}$

Accuracy of regeneration of the three color files: $\pm 1 \mu\text{m}$

The imagery was scanned through three different narrow-band interference filters (Quantum detector filters) for color separation processing. Blue, green, and red filters having 100 Å band widths (centered at 4500 and 5500 and 6500, respectively) were used successively to create three data files for each image. The dye density values in each band determined for each point in the scanned area were transformed into numbers ranging from 0 to 255. (0 represents the highest measured value, 255 represents the lowest measured value or absence of dye).

The scanning microdensitometer extracts the data in the form of a two dimensional array of numbers which are recorded on a computer compatible tape. On this tape, the analysis of the three color layers are in separate files. The OPTRON program is used at this stage to organize and annotate the scanned data. The image array produced by the scanner is input to a program in a file called DATA-FILE. From this file, other files can be created in which the original data has been revised according to a correction algorithm or otherwise manipulated for analysis. This file contains data which has been corrected for film non-linearities with the CORRECT program.

Calibration--

The Optronics P-1700 Scanning Microdensitometer was calibrated every time the light bulb in the machine was changed (every few months). A log book was kept recording each calibration.

In order to overcome the drift factor in the analysis of dye densities, the relevant step wedge (photographic image for each roll of film representing density standards) was scanned before each individual photographic image was scanned.

Investigators

Same as data set C15A1.

Supporting Documents

Same as data set C15A1.

DATA SET C15B1: IMAGE PROCESSING SOFTWARE FOR DIGITIZING COLOR AND COLOR INFRARED PHOTOGRAPHS (RS*FS)

Data Summary

Investigators--

L. Fisher, F. Scarpace, R. Kiefer, and B. Quirk.

Abstract--

This data set contains a description and instructions for use of 29 computer programs developed at the Univ. of Wisconsin-Madison to process and analyze image-based data. The RS*FS file of programs is designed to be interfaced with data (in the form of image arrays) which are produced by the Optronics P. 1700 Photomation Mark II scanning microdensitometer from remotely sensed color and color infrared photographs. The RS*FS file consists of programs which perform input to, operations upon, or output from the image array files. These programs are subject to updating; where changes have occurred, the version date is indicated for an individual program.

Data Format

Data Form--

Current executable versions of these programs are generally available in a catalogued public file in MACC mass storage named RS*FS. Source code is maintained on tapes but locations and file names vary with updates. To obtain the most up-to-date information about the current versions of these programs, interested persons should contact Dr. F.L. Scarpace at:

Department of Civil and Environmental Engineering
1235 Meteorology and Space Science Bldg.
University of Wisconsin-Madison
Madison, Wisconsin 53706
(608) 263-3973/262-3491

Descriptions of Programs--

OPTRON This program takes up to 4 tape files, one for each filter, blue, green, or red, and creates a DATA-FILE that is compatible with the other remote sensing analysis programs on the Univac system.

OUTLINE This program takes the row, column coordinates that define the boundaries of an area and moves the records within this boundary one by one from DATA-FILE to DATA-FILE 2 zeroing the values outside the boundary.

PRINT This program will print a level slice directly from a tape generating on the Optronics densitometer.

PTVALUE This program takes a row, column coordinate and prints out the band 7 value associated with that coordinate. It will also sort by row or column any series of pixel coordinates.

ROTRAIN This program is to be used in conjunction with CLASSBAR which requires that the training set data be calculated with respect to the eigenvectors corresponding to each training set. ROTRAIN transforms file 20 (output from TRAIN) into data along the eigenvectors of corresponding classes in file 21 (output from STATS).

SCALE This program transforms a DATA-FILE into a scaled image.

SLICE This program allows the user to select bounds and characters to produce line printer maps of a band or multiple bands (one at a time), of DATA-FILE.

SMOOTH This program generalizes a classified scene.

STATS This program takes training set areas from file 20 and computes statistics including: mean vectors for each class, covariance matrix for each class, inverse covariance matrix, eigen values and eigenvectors, determinants and the logarithms of the determinant.

SUBSET This program transfers a subset of the data on file DATA-FILE to the DATA-FILE 2.

TEXTURE This program calculates the standard deviation relative to each pixel for a given band and stores this value in the same band in DATA-FILE 2.

THERM This program reads and samples thermal scanner tapes and files a selected portion in DATA-FILE.

TRAIN This program extracts information from DATA-FILE for selected polygon areas and stores it in FILE 20.

File Names--

BLOCK	This program draws and numbers rectangles around any area in the DATA-FILE.
BLOWUP	This program blows up a file from 2 to 10 times by duplicating each pixel resolution squared times.
BOXCLS	This program performs a box classification on each PIXEL of DATA-FILE.
BOX 3	In this program, each picture element (PIXEL) of the DATA-FILE is examined to see if the brightness values for each band fall within the prescribed limits for the resource classes.
BOX 4	This program is a box classification that provides a minimum distance-to-mean check for overlapping classes.
COLOR	This program generates 3 color separations from DATA-FILE into DATA-FILE 2.
COPYBAND	This program will copy one band from DATA-FILE into DATA-FILE 2.
ERTSIN	This program takes all four bands on an ERTS tape and files them in a DATA-FILE format.
FALLOFF	This program corrects log exposure values in DATA-FILE for lens falloff.
FILM 70	This program generates a 9-track, 800 BPI tape to produce 26 x 64 mm film images on the Optronics P-1700 film recorder from DATA-FILE.
FILMDISPLY	This program generates a P-1700 compatible tape from one band of DATA-FILE to be used on the OPTRONICS or MCIDAS.
FILMRATIO	This program generates a ratio map from DATA-FILE and places the output in bands 4,5 and 6 of DATA-FILE 2.
FIND	This program will print out a character map containing 36 brightness levels for an area of 120 pixels square, directly from an Optronics generated tape.
MARK	This program writes a number around any pixel in DATA-FILE and places a square grid around the pixel for easier identification in photo-interpretation of the image.
MIRROR	This program transforms a data file into its mirror image.
NORMRATIO	This program calculates a normalized ratio of the bands in DATA-FILE.

Objectives--

These programs were developed prior to the Columbia project to provide a basis for computer-assisted analyses of remotely-sensed data. In the remote sensing subproject of the Columbia Impact Study, a primary objective was to develop and refine the computer techniques. At the same time, the computer programs were used to help identify and evaluate change in the wetlands west of the Columbia Generating Station.

The following list of symbols will be used to describe the U.W.-EMDAG system of image processing software:

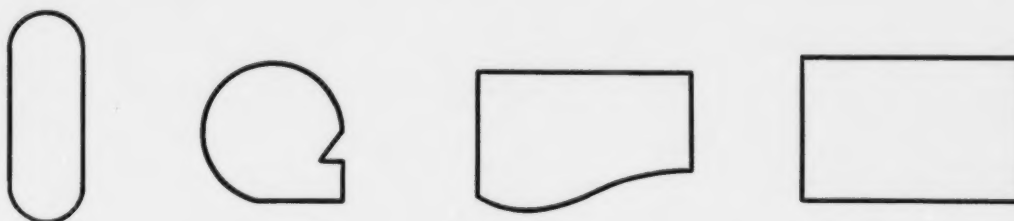
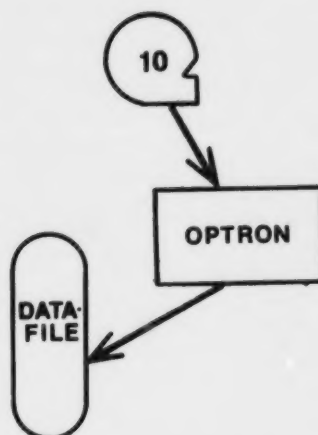
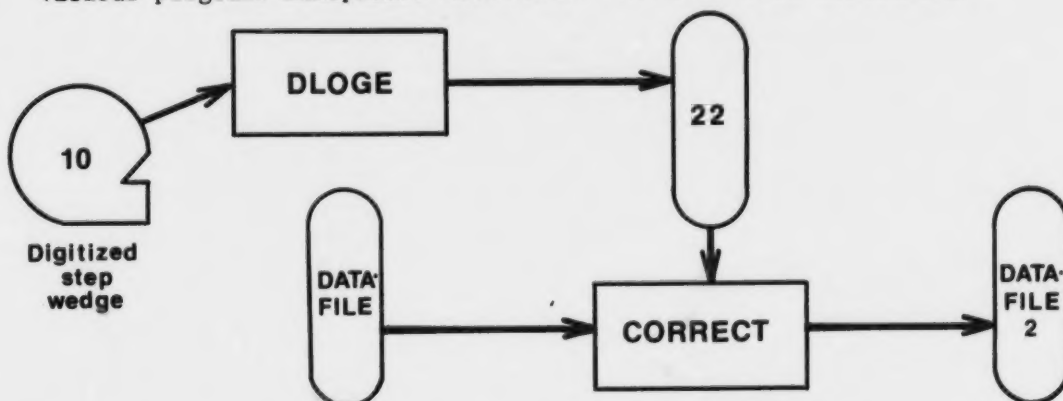


Image arrays are, by convention, always input to a program in a file called DATA-FILE, which is a format unique to these programs and which must be created by one of the input programs--OPTRON or ERTSIN. Programs that operate on the image to produce another image array use a file called DATA-FILE 2 to output their product. Other files, usually FORTRAN files, are needed to pass various information and are referred to by logic unit numbers--19, 20, 21, or 22. Tape files are always given logic unit number 10 for input, and logic unit number 12 for output. The following program is used to create an image file from a tape produced by scanning an image on the optronics scanning microdensitometer:

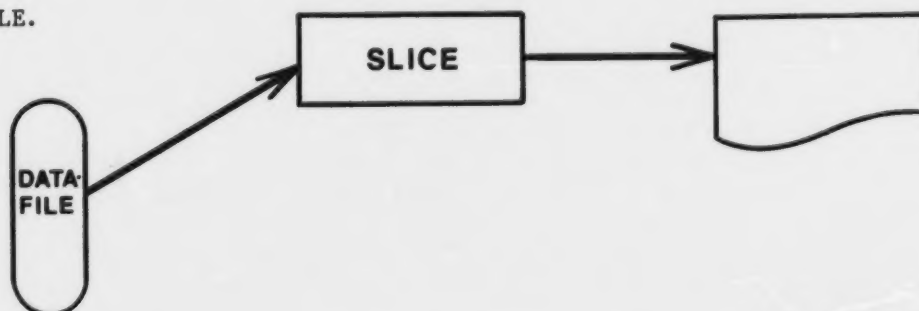


Various programs manipulate DATA-FILE. For film data correction:

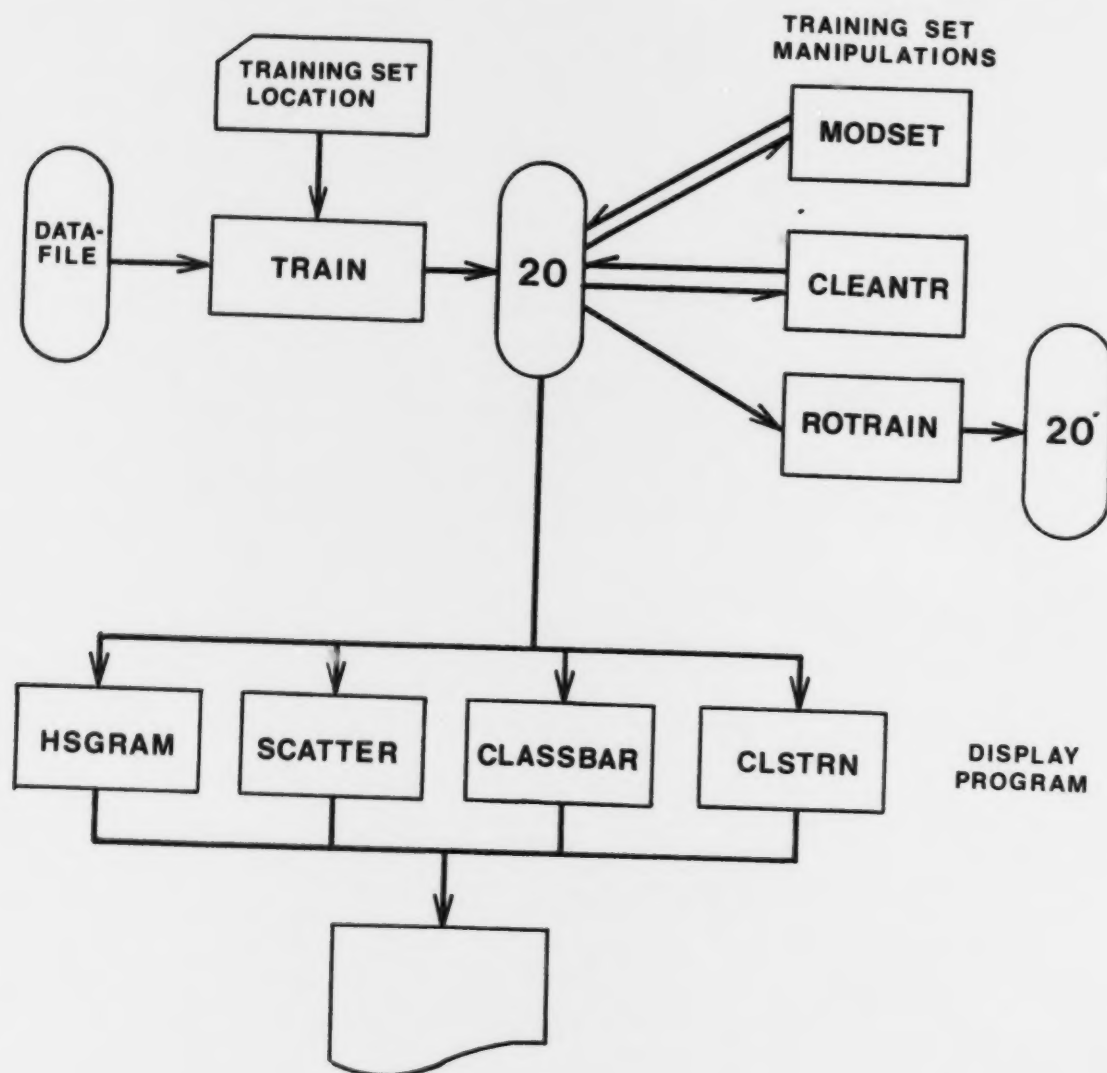


Other programs manipulate the data for enhancement: FILMRATIO, TEXTURE.

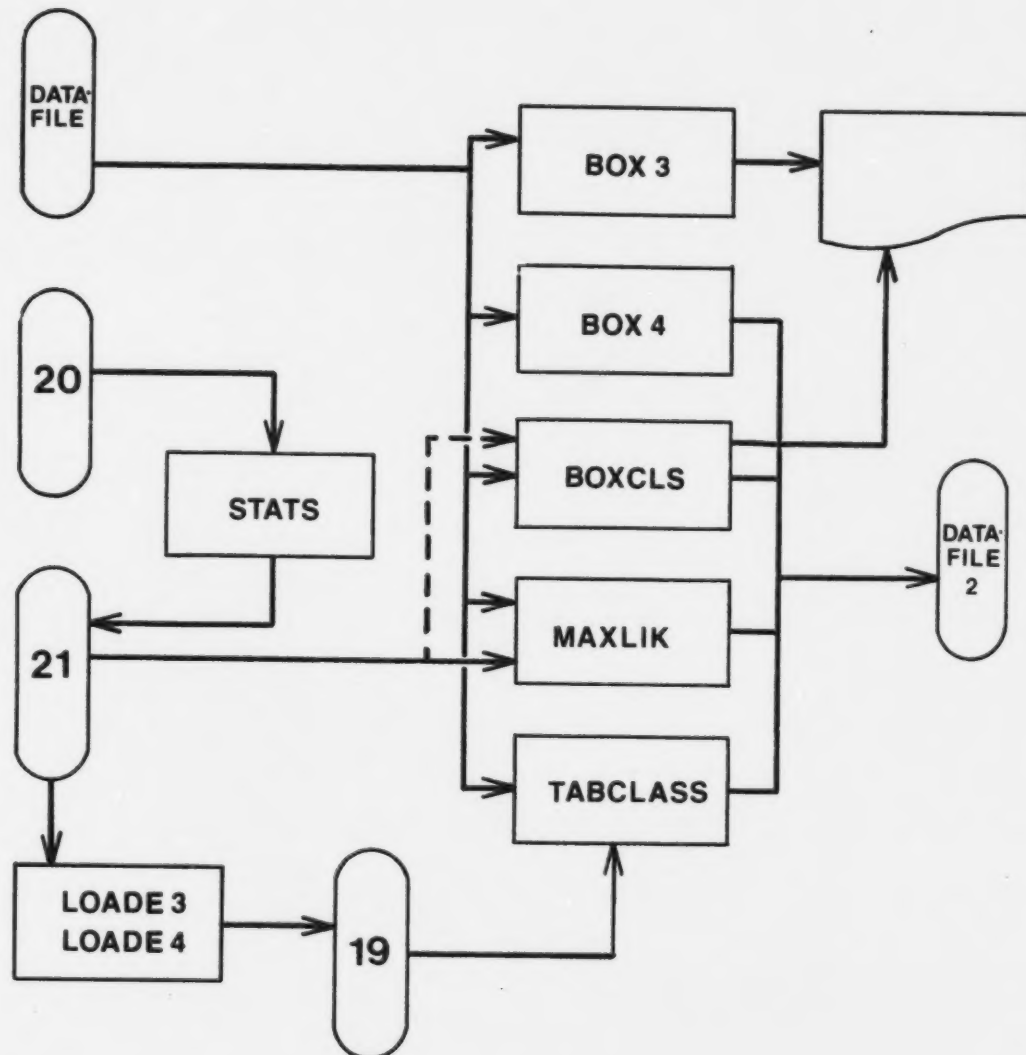
The following program can be used to produce line printer images from DATA-FILE.



The following programs can be used for extracting and manipulating training set information from DATA-FILE, to prepare for scene classification:

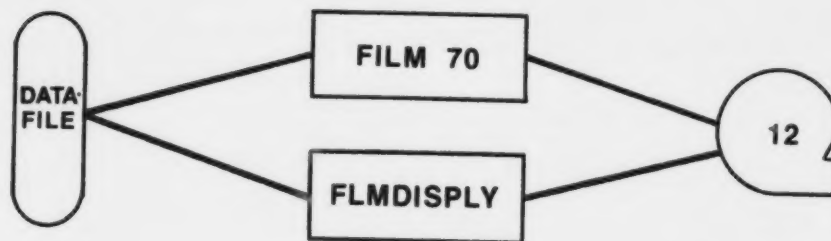


Several programs apply various algorithms to perform scene classification. Box 3, Box 4 and BOXCLS are all box or parallelepiped classifiers. MAXLIK and TABCLASS are different versions of maximum classifiers.



A group of programs provide various utility manipulations on image data producing a new image file, DATA-FILE 2:

The following programs can be used to output a DATA-FILE to a tape which can be used to produce film output with the Optronics film recorder:



DATA SET C15B2: SCANNED DATA FROM SELECTED COLOR AND COLOR INFRARED AERIAL PHOTOGRAPHS OF THE COLUMBIA GENERATING STATION SITE, HOOK LAKE, WAUBESA AND WAUNAKEE MARSHES, AND MUD LAKE (1976-77)

Data Summary

Investigators--

W. Buchanan and F. Scarpace.

Abstract--

This data set contains numerical readings derived from scanning 70-mm color and color infrared photographs of the Columbia Generating Station site (May 1976 to April 1977) and four similar wetland sites--Hook Lake, Waubesa and Waunakee marshes, and Mud Lake (30 Oct. 1976 and 6 Oct. 1976). Unit measurement size varied.

Dates of Research--

May 1976-April 1977.

Data Form--

Computer tape; high density 800 BPI nine-track tape.

File Name--

See Table 39.

Access Method--

These data files are intended for use with the RS*FS programs (refer to data set C15A1). If desired, copies of the files can be prepared on 800 or 1600 BPI magnetic tape in a format convenient for users of IBM equipment. This service is available at cost; interested parties should contact Dr. F. Scarpace.

Data Sample

Due to the nature of these data, a meaningful sample cannot be presented. It is only through further manipulation with the RS*AP programs that this data becomes useful for evaluation.

Quality Assurance

This report documents the quality assurance of data set C15B2, Scanned data from selected color and color infrared aerial photographs of the Columbia Generating Station site, Hook Lake, Waubesa and Waunakee marshes and Mud Lake (1976-77).

TABLE 39. DESCRIPTION OF FILES

Tape number	Number of files	Description	Date	Altitude (ft)	Scale	Densitometer aperture (μ)
TTS123	1-3	Stepwedge	6/17/76	1,500	1:11,500	50
	4-6	Columbia site	6/17/76			50
	7-9	Stepwedge	6/17/76			50
	10-12	Columbia site	6/17/76	2,500	1:19,100	50
	13-15	Columbia site	6/17/76	5,000	1:38,200	50
TTS174	1-3	Stepwedge	10/26/76			100
	4-6	Waubesa	10/26/76	5,000	1:38,200	100
	7-9	Hook Lake	10/27/76	5,000	1:38,200	100
	10-12	Stepwedge	10/26/76			100
	13-15	Hook Lake	10/26/76	1,000	1	100
TTS175	1	Columbia site	6/17/76	15,000	1:11,500	50
	2	Columbia site	6/17/76	25,000	1:19,100	50
	3	Columbia site	6/17/76	5,000	1:38,200	50
	4	Columbia site	6/17/76	15,000	1:11,500	50
		Corrected data				
	5	Columbia site	6/17/76	1,500	1:11,500	100
	6	Columbia site	6/17/76	2,500	1:19,100	100
	7	Columbia site	6/17/76	5,000	1:38,200	100
	8	Columbia site	7/17/76	1,500	1:11,500	50
TTS368	1-3	Junk				
		Unsmoothed				
	4-6	Hook Lake				
		Smoothed				
	7-9	Hook Lake				
TTS270	1-3	Stepwedge for Hook Lake Waubesa, Waunakee, Mud Lake				
	4-6	Hook Lake	10/3/76	5,000	1:38,200	50
	7-9	Waubesa	10/3/76	5,000	1:38,200	50
	10-12	Mud Lake	10/3/76	5,000	1:38,200	50
	13-15	Waunakee	10/3/76	5,000	1:38,200	50
TTS905	1-3	Stepwedge				50
	4-6	Hook Lake	10/6/76	10,000		100
	7-9	Columbia site	9/3/76	2,500		100
	10-12	Columbia site	9/27/76	2,500		100

Objectives--

The images of the Columbia site from 19 June 1976 were used (in conjunction with in-the-field mapping of vegetation resources) to investigate the optimum ground resolution cell size for identifying the resources present at the Columbia site, which includes upland and lowland wetlands vegetation. The entire set of scanned imagery from the Columbia site was used to investigate seasonal variation of resource spectral-signatures. Of special interest were: (1) the manner in which individual spectral signatures change over the growing season and (2) which resources were confounded. This entire set of scanned data was used to test the optimum ground-resolution cell size for identifying the vegetation resources present at several wetland sites, all similar to the Columbia site.

Monitoring Sites--

The Columbia Generating Station site is described in data set C15B1. The other four sites are all located in southeastern Wisconsin (see Figure 29).

Data Collection--

The collection of the photographs (from which these scanned data were derived) is documented in data set C15B1.

Analytical Procedure--

Same as data set C15A1.

Calibration--

Same as data set C15A1.

Adjustment of Data--

Same as data set C15A1.

Investigators--

All of this study (except the collection of the underlying photographic data) was conducted by Warren Buchanan. At the time of the experiment he was working toward a M.S. in Remote Sensing in the Institute of Environmental Studies at the University of Wisconsin-Madison. The experiment was conducted in the Civil and Environmental Engineering Laboratory at the University of Wisconsin-Madison under the supervision of Professor F. Scarpace.

Supporting Documents

Buchanan, Warren. 1978. Mapping vegetation complexes with digitized color infrared film, University of Wisconsin-Madison.

Remote sensing. In: Documentation of environmental change related to the Columbia Electric Generating Station. Institute for Environmental Studies, Reports 62, 69, 82, and 92, University of Wisconsin-Madison.

SECTION 16

CITIZEN CONCERNS AND ATTITUDES

The purpose of the study was to identify the major economic and environmental concerns, attitudes, and values held by persons living near present power plants or potential sites of future power plants. All possible types of power plants were included, and the study was designed to represent all interest groups as equally as possible.

The study included two data sets, data set C16A1 and data set C16A2. Data set C16A1 (Citizen workshop: Participants' attitudes and concerns) includes the results of four workshops held in the spring of 1977. Data set C16A2 (Citizen workshop: The survey) includes the results of a survey of issues not covered by the workshops.

The investigators were Bruce Murray, a professor in the Department of Landscape Architecture of the University of Wisconsin-Madison and Elin Quigley and Jill Randall, project assistants at the Institute for Environmental Studies of the University of Wisconsin-Madison. The report was compiled by Saya Shacham, Data Analyst, Water Resources Center.

DATA SET C16A1: CITIZEN WORKSHOP: PARTICIPANTS' ATTITUDES AND CONCERNS

Data Summary

Investigators--

E. Quigley, J. Randall, and B.H. Murray.

Abstract--

In spring 1977 four workshops concerning power-plant siting were organized by researchers from the University of Wisconsin-Madison. The purpose of the workshops, held in Janesville, Eau Claire, Stevens Point, and Sheboygan, Wisconsin, was to enable residents of the area to express their concerns about the location and possible impact of power plants. A total of 215 invited participants from 17 Wisconsin counties spent an entire day at 1 of the 4 workshops expressing their concerns, attitudes, and values on power plant siting.

This data set, containing the results of these workshops, lists all the concerns, the results of an intermediate vote to rank concerns, and the final rankings of concerns by each group.

Dates of Research--

Spring 1977.

Data Sample

No data sample is presented for data set C16A1.

Quality Assurance

Objectives--

The goal of the workshops was to identify the major economic and environmental concerns, attitudes, and values held by persons living near present or future generating-facility sites. Positive and negative aspects of power plant siting were considered, and all possible types of power-plants were included.

Workshop Format--

The workshops were held in four towns in Wisconsin: Janesville, Eau Claire, Stevens Point, and Sheboygan. The participants came from 17 Wisconsin counties (Figure 29).

Since the goal of the workshops was to identify attitudes rather than provide a forum for discussion, a fairly rigid format was followed. After registration and a brief introduction, participants were divided into groups of 8-10 persons, representing a variety of interests. Each group was led by a University of Wisconsin staff member familiar with the program. The group leaders coordinated and recorded the information developed by the groups but did not join in the process of listing or ranking concerns.

A method of group participation known as the nominal-group technique was used. Developed by Professor Andre Delbecq of the School of Business, University of Wisconsin-Madison, the technique minimizes discussion and moves quickly to identify the important concerns. A round-robin sequence gave each participant an equal input to the results.

This workshop format was designed to provide information that could not be obtained by a survey or public hearings, since in the small groups each individual could contribute to the listing and voting. The small groups also allowed for the exchange of ideas and viewpoints--positive and negative--which are reflected in the final list.

Concerns of the participants were divided into three general areas: biological and physical, economic and social, and land use. Participants were given 10 min. to work independently on lists of their 10 most important concerns in each area. The group leader then asked each participant to contribute to the group's collective list. The round-robin continued until all concerns were listed. Many concerns not listed during the 10 min. period arose as the collective list was developed. After completion and discussion of the collective list, each participant was asked to choose what



Figure 29. Map of Wisconsin showing the counties from which participants came to attend the citizen concern workshops.

he or she considered to be the 10 most important concerns from the list created for each of the three categories. A vote was taken on these concerns with 10 points going to the participant's most important concern, 9 points to the second most important concern, and so on down to 1 point for the tenth concern, the least important one. A list was compiled on the group's top 10 concerns about power-plant siting in each of the three areas. In the final vote participants voted for the 10 most important concerns of the top 30 concerns, 10 from each category.

The Participants--

The participants were recruited by letters sent to interested groups. Participants were recommended by county extension agents, officials from the Wisconsin Department of Natural Resources (WDNR) and the Wisconsin Public Service Commission (WPSC), local officials, members of regional planning commissions, chambers of commerce, and state and local interest groups such as the Farm Bureau, environmental organizations, the League of Women Voters, and many others.

Those attending the workshops included farmers, union members, elected local and county officials (including several mayors and county board chairmen), county and state employees, representatives of commercial, industrial, recreational, and environmental interests, and members of the League of Women Voters and concerned citizens.

Table 40 shows the occupations and fields of interests of participants in the different workshops.

The Data--

The data include the results from each group separately. For each group the concerns raised for each of the three major categories are listed and organized according to the number of points received by each concern. Also the final vote of each group is given. Finally, the data include the names and number of the participants in each group. Some concerns were more general than others, and the more general items tend to receive more votes and more points.

Investigators--

The study was designed and analyzed by E. Quigley and J. Randall. Elin Quigley received her Ph.D. in Land Resources from the University of Wisconsin-Madison in 1977. J. Randall received her M.S. in Landscape Architecture from the University of Wisconsin-Madison in 1976. B. Murray, a Professor in Landscape Architecture, University of Wisconsin-Madison, was the principal investigator.

TABLE 40. OCCUPATIONS AND FIELDS OF INTEREST OF PARTICIPANTS AT FOUR CITIZEN WORKSHOPS HELD IN WISCONSIN CITIES IN SPRING 1977^a

Occupations or fields of interest	Locations of workshops			
	Janesville	Eau Claire	Stevens Point	Sheboygan
Interested citizens and community organizations	15	9	8	5
Government and elected officials	14	7	16	15
Farming	10	8	6	5
Business	12	7	15	6
Environmental and consumer groups	7	6	7	5
Recreation and tourism	3	-	1	2
Other	<u>7</u>	<u>9</u>	<u>5</u>	<u>5</u>
Total	68	46	58	43

^aAdditional information about the participants is presented in the Quality Assurance section of data set C16A2.

Supporting Documents

Quigley, E., J. Randall, B. Murray, and A. D'Alessio. 1980. Citizen concern with power plant siting. U.S. Environmental Protection Agency, Cincinnati, Ohio. In press.

DATA SET C16A2: CITIZEN WORKSHOP: THE SURVEY

Data Summary

Investigators--

E. Quigley, J. Randall, and B.H. Murray.

Abstract--

This data set contains the result of a survey conducted to address questions not covered by the citizen workshops (data set C16A1). In the survey, participants were asked (1) to rate various kinds of sites (for example, industrial, commercial, agricultural, or wetland areas) for a

nuclear power plant, a coal-fired power plant, and transmission lines; (2) to express their willingness to accept a power plant nearby to meet increased electrical demand elsewhere in the state; (3) to provide information on their occupation, age and whether or not they live near a power plant; and (4) to express their views on the workshop.

Data Form--

The data are stored in 80-character card-image form on a magnetic tape. The file contains 190 units of 2 card images each.

Data Format

Field Description--

Card #1

Column	Format	Description
1	I1	City code; 1=Janesville, 2=Eau Claire, 3=Stevens Point, 4=Sheboygan
2-3	I2	Questionnaire identification number
4	I1	Image sequence, 1 for card 1
5-23	19I1	Question 1. Rating of 19 siting possibilities for nuclear power plants: 1=Very poor location, 2=Poor location, 3=No opinion, 4=Good location, 5=Very good location
24-30	7I1	Question 2. Ranking of seven siting possibilities for nuclear power plants
31	I1	Question 3. (same code as question 1)
32	I1	Question 4. (same code as question 1)
33	I1	Question 5. Comparison of one large power plant to many small ones; 3=Better than, 2=Same, 1=Worse than
34	I1	Question 6. Opinion of power-plant construction changed by new tax laws? 1=Yes, 2=No
35	I1	Question 7. How was opinion changed in question 6? 1=Much more positive, 2=More positive, 3=Somewhat more negative, 4=Much more negative
36	I1	Question 8. Distance of residence from power plant: 1=Don't know, 2=Within 5 miles, 3=5-10 miles, 4=More than 10 miles
38	I1	Question 9. Can power plant be seen from residency site: 1=Don't know, 2=No, 3=Yes
39-46	8I1	Question 11. Ranking of eight siting possibilities for transmission-line suitability
47	I1	Question 12. Years lived in area: 1=Less than 1 year, 2=1-5 years, 3=5-10 years, 4=More than 10 years
48-55	8I1	Question 13. Social-organization membership of eight types of organizations: 0=Non-member, 1=Member

56-57	I2	Question 14. Occupation: 1=Farmer, 2=Agribusiness, 3=Business, 4=Educator or student, 5=County official or agent, 6=Professional, technical, 7=Non-professional, 8=Engineer, 9=Retired, 10=Other
58	I1	Question 15. Age: 1=21-35, 2=36-50, 3=51 and over
59	I1	Question 16. Overall rating of workshop: 1=Poor, 2=Fair, 3=Good, 4=Excellent
60	I1	Comments made: 0=No, 1=Yes
61-79	19I1	Question 17. Rating of 19 possible sites for coal-fired power plants. Ratings and sites same as question 1.

Card #2

1	I1	City code
2-4	I2	Questionnaire identification number
4	I1	Image sequence, 2 for card #2
5-11	7I1	Question 18. Ranking of seven siting possibilities for a coal-fired power plant

Missing Data--

Missing data are indicated by blanks.

Data Sample

The sample presents 8 units, 147 to 154, out of 190 units included in data set C16A2.

12345678901234567890123456789012345678901234567890123456789012345678901234567890
346145242422255 5 53345765412355310232584716234000010000933155 4 52 2 55 5 4 5
34626742135
3471114411112444422224572664342110322175648233111001006331454522112222112212
34726713245
34811111111111111111177777775 11032377777774110111100432145224411111111111
3482 21
3491224422112554455 422563472154 2141148563721410110110934144 22222444242244
3492
3501244455122445422 136427543310422867542134 1 07340242455242444445544
35027645312
3511125422113543433553337256143132013258647312200010000072404555441242424224545
35127432165
400111111111111111111637214521110423631 245740100010108241541144221111111111
40025342167
4011 1452222224422332267453215322322226517834400001000033415 22111111155115511
40127534261

Quality Assurance

Objectives--

The principal objective of the survey in data set C16A2 was to address issues not covered by the workshops (data set C16A1), especially issues

concerning the trade-offs between various land uses (for example, industrial areas, agricultural areas, and natural areas) in selecting sites for power plants and transmission lines. Also of interest were participants' reactions to having a local power plant that supplies power elsewhere in the state, preferences for one large or several smaller plants to meet approximately the same energy needs, and general reactions to Wisconsin tax laws.

The Respondents--

The respondents represented a broad spectrum of age groups and professional backgrounds. Of those who completed the questionnaire (190 of the 215 workshop participants), 26.7% were aged 21-35, 28.3% were 36-50, and 45% were 50 or older. Of these respondents, 13.2% were farmers, 14.9% were business people, 11% were educators, 8.2% were government officials or employees, 14.3% represented other professions (such as doctors, historians, and artists), and 38.1% were either individuals employed in other fields, housewives, or retired persons. The percentage of government officials identified by the survey is much lower than the actual percentage among the participants. A possible reason could be that government workers primarily identified themselves by occupation and not as government employees.

Respondents tended to be long-term residents actively involved in their communities; 64.7% had lived in their current residential area for more than 10 yr, and 56.3% were currently members of civic organizations. Additional information about the participants is presented in the Quality Assurance section in data set C16A1.

The Survey--

A sample of the survey is found in Figure 30. To simplify analysis most of the questions used a 7-point "Likert" type scale. However, some of the questions were open-ended.

The questionnaire asked participants (1) to rate various kinds of sites (for example, industrial, commercial, agricultural, or wetland areas) for a nuclear power plant, a coal-fired power plant, and transmission lines; (2) to express their willingness to accept a power plant to meet increased electrical demand elsewhere in the state; (3) to provide information on their occupation, age, and whether or not they live near a power plant; and (4) to express their views on the workshop.

Investigators--

Same as data set C16A1.

Supporting Documents

Same as data set C16A1.

THE SURVEY

SPECIAL SURVEY FOR WORKSHOP PARTICIPANTS

WE WOULD APPRECIATE YOUR HELP IN ANSWERING THE FOLLOWING QUESTIONS, WHICH MAY NOT BE COVERED DURING THE WORKSHOP. YOUR ANSWERS WILL BE AN IMPORTANT COMPONENT OF THE SUMMARY REPORT.

How would you rate each of the following areas as a potential nuclear power plant site? Please circle the number which indicates your rating of each type of area. Please read all the categories before you start circling your answers.

	VERY POOR LOCATION	POOR LOCATION	NO OPINION	GOOD LOCATION	VERY GOOD LOCATION
IN HEAVILY INDUSTRIAL AREAS	-2	-1	0	+1	+2
NEAR (WITHIN 2 MILES OF) HEAVILY INDUSTRIAL AREAS	-2	-1	0	+1	+2
IN AGRICULTURAL AREAS	-2	-1	0	+1	+2
NEAR AGRICULTURAL AREAS	-2	-1	0	+1	+2
IN LIGHT COMMERCIAL AREAS	-2	-1	0	+1	+2
NEAR LIGHT COMMERCIAL AREAS	-2	-1	0	+1	+2
IN RESIDENTIAL AREAS	-2	-1	0	+1	+2
NEAR RESIDENTIAL AREAS	-2	-1	0	+1	+2
NEAR PARK AREA	-2	-1	0	+1	+2
IN FOREST AREAS	-2	-1	0	+1	+2
NEAR FOREST AREAS	-2	-1	0	+1	+2
ON GREAT LAKES SHORELINES	-2	-1	0	+1	+2
NEAR GREAT LAKES SHORELINES	-2	-1	0	+1	+2
ON SHORES OF SMALLER LAKES	-2	-1	0	+1	+2
NEAR SHORES OF SMALLER LAKES	-2	-1	0	+1	+2
IN WETLANDS	-2	-1	0	+1	+2
NEAR WETLANDS	-2	-1	0	+1	+2
ON RIVERBANKS	-2	-1	0	+1	+2
NEAR RIVERBANKS	-2	-1	0	+1	+2

Figure 30. Sample of Citizen Concerns Workshop survey.

How would you feel about the location of a power plant in your area, under each of the following two conditions?

	STRONGLY NEGATIVE	NEGATIVE	NEUTRAL	POSITIVE	STRONGLY POSITIVE
1. The power plant would basically supply energy to your area.	-2	-1	0	+1	+2
2. The plant would basically supply energy to other parts of the state.	-2	-1	0	+1	+2

To supply about the same amount of power, do you think one large plant would be _____ better than _____ about the same as, or _____ worse than several smaller plants?

Have the new tax laws changed the way you would feel about the construction of a power plant in your community?

_____ YES _____ NO

If "yes," how have your feelings changed?

much more negative somewhat more negative more positive much more positive

About how far do you live from any existing power plant?

_____ less than 5 miles _____ from 5-10 miles _____ further than 10 miles

Can you see the power plant from where you live?

_____ YES _____ NO _____ Don't know

Can you see high voltage transmission lines from where you live?

_____ YES _____ NO _____ Don't know

We would like you to rank the following 8 types of areas for their suitability for high-voltage transmission lines, from "1" (most suitable) through "8" (least suitable).

Please write the appropriate number in the space next to each item.

_____ AGRICULTURAL LAND	_____ COMMERICAL AREAS
_____ RESIDENTIAL AREAS	_____ PARKS
_____ INDUSTRIAL AREAS	_____ WETLANDS
_____ SHORELINE AREAS	_____ FORESTS

For how many years have you lived in this area?

_____ less than 1 _____ 1-5 years _____ 5-10 years _____ more than 10

Next we would like you to rank the following seven types of areas for their suitability for a power plant site, from "1" (most suitable) through "7" (least suitable). Please write the appropriate number in the space next to each item.

☐ PARKS	☐ HEAVILY INDUSTRIAL AREAS
☐ RESIDENTIAL AREAS	☐ NATURAL AREAS
☐ AGRICULTURAL AREAS	☐ SHORELINE AREAS
☐ LIGHT COMMERCIAL AREAS	

Do you presently belong to any of the following types of organizations, associations or clubs, or have you belonged within the past three years? Please check each appropriate choice.

☐ AGRICULTURAL	☐ SPORTS OR RECREATIONAL
☐ ENVIRONMENTAL	☐ POLITICAL
☐ BUSINESS	☐ CIVIC
☐ PROFESSIONAL	☐ OTHER _____

What is your occupation? Please be as specific as possible.

What is your age?

21-35 36-50 50+

Overall, how would you rate the Power Plant Siting Workshop?

☐ POOR
☐ FAIR, BUT COULD HAVE BEEN BETTER
☐ GOOD, ONLY MINOR PROBLEMS
☐ EXCELLENT

If you would like to comment on any aspect of the workshop or the concerns addressed, please tell us about them in the space below.

THANK YOU VERY MUCH FOR YOUR HELP.

One additional sheet--

How would you rate each of the following areas as a potential. COAL power plant site? Please circle the number which indicates your rating of each type of area. Please read all the categories before you start circling your answers.

	VERY POOR LOCATION	POOR LOCATION	NO OPINION	GOOD LOCATION	VERY GOOD LOCATION
IN HEAVILY INDUSTRIAL AREAS	-2	-1	0	+1	+2
NEAR (WITHIN 2 MILES OF) HEAVILY INDUSTRIAL AREAS	-2	-1	0	+1	+2
IN AGRICULTURAL AREAS	-2	-1	0	+1	+2
NEAR AGRICULTURAL AREAS	-2	-1	0	+1	+2
IN LIGHT COMMERICAL AREAS	-2	-1	0	+1	+2
NEAR LIGHT COMMERICAL AREAS	-2	-1	0	+1	+2
IN RESIDENTIAL AREAS	-2	-1	0	+1	+2
NEAR RESIDENTIAL AREAS	-2	-1	0	+1	+2
NEAR PARK AREA	-2	-1	0	+1	+2
IN FOREST AREAS	-2	-1	0	+1	+2
NEAR FOREST AREAS	-2	-1	0	+1	+2
ON GREAT LAKES SHORELINES	-2	-1	0	+1	+2
NEAR GREAT LAKES SHORELINES	-2	-1	0	+1	+2
ON SHORES OF SMALLER LAKES	-2	-1	0	+1	+2
NEAR SHORES OF SMALLER LAKES	-2	-1	0	+1	+2
IN WETLANDS	-2	-1	0	+1	+2
NEAR WETLANDS	-2	-1	0	+1	+2
ON RIVERBANKS	-2	-1	0	+1	+2
NEAR RIVERBANKS	-2	-1	0	+1	+2

Next we would like you to rank the following seven types of areas for their suitability for a COAL fired power plant site, from "1" (most suitable) through "7" (least suitable). Please write the appropriate number in the space next to each item.

____ PARKS
 ____ RESIDENTIAL AREAS
 ____ AGRICULTURAL AREAS
 ____ LIGHT COMMERICAL AREAS

____ HEAVILY INDUSTRIAL AREAS
 ____ NATURAL AREAS
 ____ SHORELINE AREAS

SECTION 17

WISCONSIN POWER AND LIGHT COMPANY

This subproject includes several types of monitoring data necessary to evaluate the emission of air contaminants from the stacks of Units I and II of the Columbia Generating Station. Specific objectives were: (1) to monitor air quality levels around the Columbia Generating Station; (2) to monitor the meteorological system in the vicinity of the power plant in order to identify how materials are transported through the atmosphere; and (3) to monitor plant operation to determine stack discharge levels.

Relating to objective (1), three different air quality measurements were obtained. These data are presented in data sets C17A1, C17A2, and C17A3. Data set C17A1 (Sulfur dioxide (SO_2) monitoring near the Columbia Generating Station (1976-79)) contains hourly average records of ambient SO_2 recorded at seven sites. Data set C17A2 (Ozone monitoring at the Genrich site of the Columbia Generating station (1976-78)) contains hourly average records of O_3 recorded at the Genrich site. Data set C17A3 (Total suspended particulates near the Columbia Generating Station (1976-79)) contains 24-hr averages of TSP obtained every 6 days at four sites.

Relating to objective (2), monitoring the meteorological system around the Columbia Generating Station, eight types of measurements were made. The data collected in these studies are presented in data sets C17B1 through C17B8. Data set C17B1 (Air temperature near the Columbia Generating Station (1976-78)) contains hourly average records of air temperature obtained at two sites. Data set C17B2 (Air temperature gradient at the Tower site near the Columbia Generating Station (1976-79)) contains hourly average records of air temperature differences between a pair of measurement points at the Tower site. Data set C17B3 (Wind-speed monitoring near the Columbia Generating Station (1976-79)) contains hourly average records of wind speed measured at two sites. Data set C17B4 (Horizontal wind direction measurements near the Columbia Generating Station (1976-78)) contains hourly average records of horizontal wind direction obtained at two sites, Lake and Tower. Data set C17B5 (Measurements of vertical wind direction near Columbia Generating Station (1977-79)) contains hourly average records of vertical wind direction obtained at the Tower site. Data set C17B6 (Precipitation monitoring near the Columbia Generating Station (1976-79)) contains hourly average records of precipitation obtained at the Lake site. Data set C17B7 (Atmospheric pressure near the Columbia Generating Station (1976-78)) contains hourly average records of atmospheric pressure obtained at the Lake site. Data set C17B8 (Net radiation measured near the Columbia Generating Station (1976-79)) contains hourly average records of net radiation obtained at the Tower site.

Relating to objective (3), power plant operation, two types of data were obtained. The data collected in these studies are presented in data sets C17C1 and C17C2. Data set C17C1 (Gross megawatt load of the Columbia Generating Station (1975-78)) contains hourly average records of electric power generated by Unit I of the Columbia Generating Station. Data set C17C2 (Daily coal consumption of the Columbia Generating Station (1975-78)) contains daily records of the amount of coal fed into Unit I of the Columbia Generating Station.

Plant operating data were collected by the Wisconsin Power and Light Company (WPL) the principal operator of the Columbia Generating Station. Air quality and meteorology data were collected by Dames and Moore, consultants in Environmental and Applied Earth Sciences based in Park Ridge, Illinois. The air quality and meteorology monitoring were initiated in May 1976 as recommended by Dames and Moore and approved by WPL, WDNR and WPSC. The data collection and the equipment maintenance were all performed by Dames and Moore.

The report was compiled by Saya Shacham, Hilary McLellan, and Eric Loucks, Water Resources Center.

DATA SET C17A1: SULFUR DIOXIDE (SO₂) MONITORING NEAR THE COLUMBIA GENERATING STATION (1976-79)

Data Summary

Investigators--

Dames and Moore, Inc., Park Ridge, Illinois, under contract with WPL.

Abstract--

This data set contains hourly average records of ambient SO₂ (µg/m³) measured from March 1976 to Feb. 1979. The measurements were recorded at seven sites located 4.4 to 15 km from the Columbia Generating Station.

Dates of Research--

March 1976-June 1978.

Data Form--

Computer file containing 12,737 units with one card-image/unit.

Data Format

Field Description--

All data sets in part C17A use the same modified Storage and Retrieval of Aeromatic Data (SAROAD) field description as follows.

<u>Column</u>	<u>Format</u>	<u>Description</u>
1-3	I3	State identifier; 151=Wisconsin
4-7	I4	Location identifier; 0600=Columbia County, 2780=City of Portage
8-10	I3	Site; 002=Cemetery, 003=Lake George, 004=Dekorra, 005=Messer, 008=Genrich, 009=Russell, 010=Bernander
11	A1	Funding agency type; J=private
12-13	I2	Project classification; 02=source oriented ambient surveillance
14	I1	Time interval between measurements; 1=1 hr, 7=6 days
15-16	I2	Year
17-18	I2	Month
19-20	I2	Day
21-22	I2	Hour of first measurement (column 33) (24 hr clock)
23-27	I5	Parameter code; 42401=SO ₂ (data set C17A1), 44201=O ₃ (data set C17A2), 11101=24 hr total suspended solids (data set C17A3)
28-29	I2	General method code, 11=chemiluminescence (data set C17A2), 13=conductometric (data set C17A1), 14=coulometric (data set C18A1), 91=gravimetric (data set C17A3)
30-31	I2	Units of data; 01=μg/m ³ (25°C, 1013 mb)
32	I1	Decimal locator (columns from right)
33-80	12I4	Observations

Missing Data--

Missing data are indicated by 9999.

Data Sample

The sample presented here is 10 records, 320 to 329 of the 12,737 records included in data set C17A1.

123456789012345678901234567890123456789012345678901234567890

1510600005J0217604071242401140109999	66	44	44	44	22	22	22	43	21	21	21
1510600005J021760408004240114010	21	21	21	21	21	21	21	22	22	22	22
1510600005J021760408124240114010	22	22	22	22	22	22	5	22	43	21	64
1510600005J021760409004240114010	21	21	21	21	21	21	21	22	22	44	22
1510600005J021760409124240114010	22	23	23	23	23	22	22	22	22	22	22
1510600005J021760410004240114010	22	43	43	43	22	22	22	22	44	44	45
1510600005J021760410124240114010	23	23	23	22	22	22	22	22	22	21	21
1510600005J021760411004240114010	21	21	21	21	21	21	21	21	21	21	21
1510600005J021760411124240114010	21	22	22	22	22	65	43	21	21	21	21
1510600005J021760412004240114010	21	21	21	21	21	21	21	22	22	22	22

Quality Assurance

Objectives--

The objective of the study was to characterize air quality in the vicinity of the Columbia Generating Station to assess the station's

environmental impact. The SO₂ data was collected by Dames and Moore, Inc., under subcontract from the WPL to meet WPSC requirements.

Monitoring Sites--

At the program's inception, SO₂ monitoring was undertaken at the Cemetery, Dekorra, Lake George and Messer sites (Figure 31). The locations of these sites were determined by a prediction model which predicted where the high concentrations of SO₂ would occur and the frequency and probability of these occurrences. In addition, some sites were selected to test the effect of SO₂ at different distances from the Columbia Generating Station. Monitoring at the above sites commenced on 1 March 1976. On 7 May of that year, monitoring was started at three other sites, Genrich, Russell, and Bernander.

Wind records for Madison, WI show that easterly winds are relatively infrequent so that a site directly west of the Columbia Generating Station would be the least affected by the power plant. The Messer site was established 7.1 km west of the Columbia Generating Station on the Baraboo Hills at an elevation of 390 m above MSL. The local area is characterized by open forest interspersed with farm fields. The Baraboo Hills continue to rise to the west of the Messer site, while the bluffs drop sharply to the Wisconsin River valley < 500 m to the north and east of the site.

The Dekorra site was established 4.2 km southwest of the power plant and only 4 km from the eastern base of the Baraboo Hills at an elevation of 245 m above MSL. Exposure to the wind was quite good in directions other than the west. The area surrounding the site is characterized by open forest and is more rolling than the other valley sites.

The Cemetery site was established just to the north of Portage, WI, and 9.7 km north of the power plant at an elevation of 250 m above mean sea level. The only obstruction was a small stand of 10-m high trees at a distance of 150 m to the south of the site. The terrain, consisting mostly of open forest, was quite flat away from the site.

The Lake George site, located in an open area just east of Lake George is approximately 6.3 km northeast of the Columbia Generating Station in the Wisconsin River valley, at an elevation of 250 m above MSL.

The Genrich site is located directly north of the Columbia Generating Station at a distance of approximately 9 km. This site is located east of Portage in the Wisconsin River valley, at an elevation of 245 m above MSL.

Russell is the site located furthest from the Columbia Generating Station, at a distance of 16 km to the northeast. This site, at an elevation of 275 m above MSL, is located in an open area adjacent to a slight elevation to the north and west.

The Bernander site is located 15 km east of the power plant, at an elevation of 255 m above MSL. It is situated in an area of open, unobstructed fields.

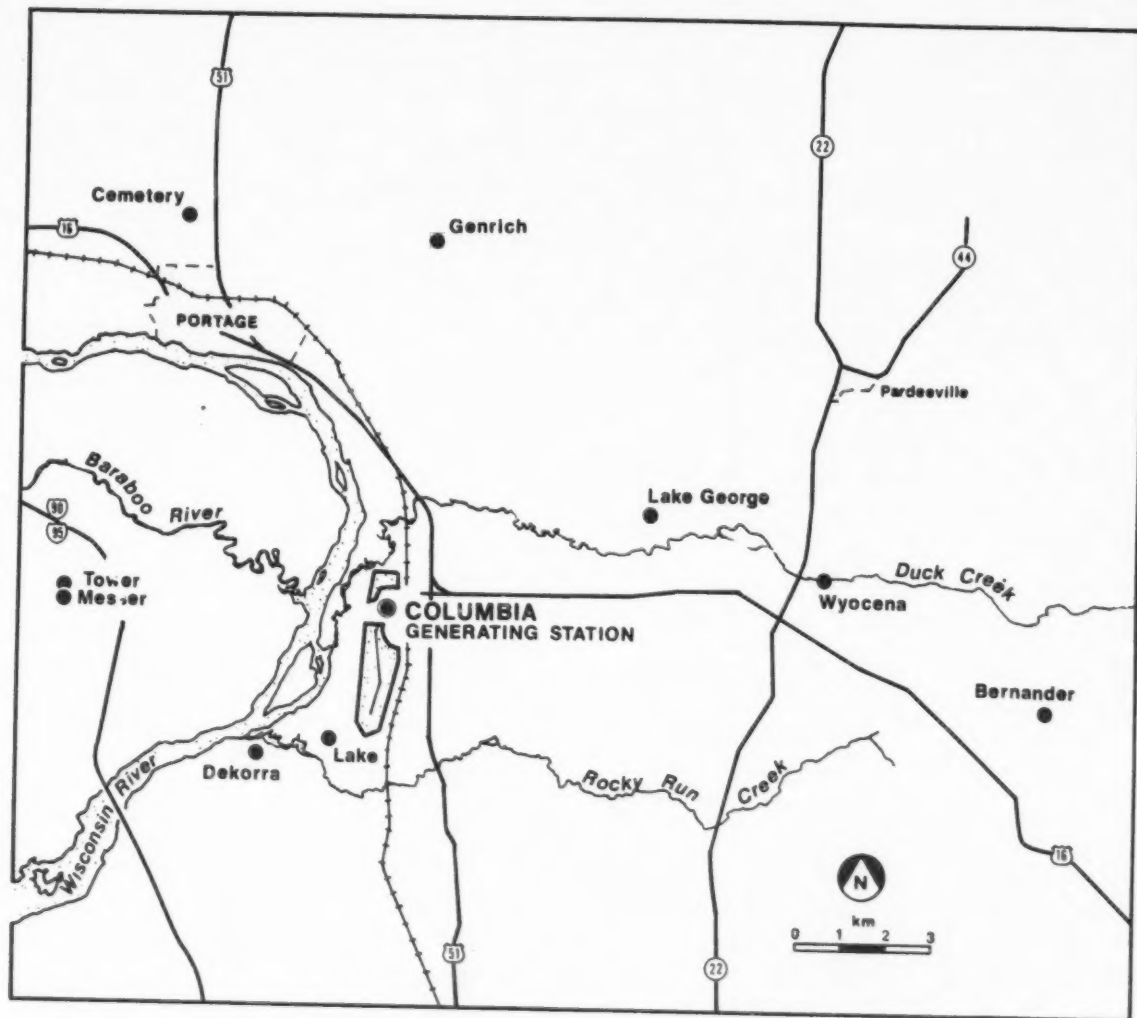


Figure 31. Dames and Moore monitoring sites for meteorology and air quality studies.

Monitoring Equipment--

The SO₂ monitoring equipment at each of the sites included:

- (1) Philips PW 9700 SO₂ Monitor
- (2) Esterline-Angus L1101S Single Channel Speed Servo II Recorder
- (3) Monitor Labs 8640 Averager
- (4) SO₂ intake which was approximately 15 ft above the surface

The Philips PW 9700 SO₂ Monitor converts the SO₂ concentration that is present into an electrical signal which can be compared to a known signal. Technical specifications which are of interest:

Detection limit: $< 10 \mu/m^3$

Zero drift: $< 25 \mu/m^3$

Accuracy: Better than 15% of the measuring signal.

During 1978 the Philips PW 9700 SO₂ Analyzers were replaced with Meloy SA-285 Sulfur Analyzers. The following list summarizes the dates by site for which the Meloy SA-285 Analyzers became operational:

Genrich--16 March 1978

Dekorra--29 April 1978

Russell--22 Aug. 1978

Lake George--24 Aug. 1978

Messer--30 Aug. 1978

Bernander--30 Oct. 1978

Site Checks and Calibration--

All monitoring sites were checked 3 times/week by a Senior Field Technician employed on a full-time basis by Dames and Moore and based in the Portage area.

The daily site checks included routine inspection of all instruments and recorders to ensure proper operation, changing strip charts, and filling out a detailed checklist of all equipment checks.

In addition to the checklist, each site visit, routine or otherwise, was recorded in a log book which was maintained at each site. All instrument outages or possible problems were noted in the log.

Separate log books also were maintained for each air quality analyzer to provide a complete operation record for each instrument, regardless of location.

The accuracy of proper operation of all SO₂ instruments were verified through detailed calibration procedures carried out at 3-month intervals using the Monitor Lab 8500 Permacal Calibrator. Calibrations were performed by the local Senior Field Technician in conjunction with a Senior Instrument Technician from the Dames and Moore Park Ridge office. All instruments were calibrated under the same conditions that existed during normal operation, and at the same sites.

Detailed records were kept of each calibration, including "before" and "after" readings for each instrument. A detailed memorandum also was filed for each calibration.

Data Reduction--

Hourly average values for SO₂ concentration were obtained directly from analog strip charts by the Senior Field Technician. These averages were coded on keypunch forms. The strip charts and the coded forms were forwarded weekly to the Dames and Moore Park Ridge Office.

The strip charts and the coded averages were reviewed by a staff meteorologist in the Park Ridge office to ensure completeness and accuracy of the data, and to identify any problems in the data acquisition process. After review, the coded averages were keypunched and the punched cards were verified for accuracy prior to analysis of the data.

All SO₂ concentrations were corrected to Standard Temperature and Pressure (25°C and 1013 mb) in accordance with the U.S. EPA Storage and Retrieval of Aerometric Data (SAROAD) format.

Adjustment of Data--

Variation between calibration curves for a given monitor during successive calibrations (i.e., comparing the post-maintenance calibration curve of the preceding calibration with the pre-maintenance calibration curve of the following calibration; adjustment of the data was made in some instances. The adjustments were made when the corrections exceeded 3% of full scale.

Generally, the errors found were corrected using the following method. It was assumed that the error was zero after the previous calibration and that a linear error drift occurred during the time period between calibrations. A computer program, CORRECT, was developed by the Dames and Moore Company, to correct the data in the period between the two calibrations. The program used the following equation:

$$\text{VALUE}_n = \frac{I \text{ HOUR}}{N \text{ HOUR}} [a_0 + a_1 (\text{VALUE}_0)] + \text{VALUE}_0 \quad (8)$$

where VALUE_n = new (corrected) value of the variable of interest, VALUE₀ = old (uncorrected) value of the variable of interest, I HOUR = The ith hour of the period of interest, N HOUR = The total number of hours in the period of interest, a₀a₁ = Correction factor (intercept and slope of the error function respectively). Significant data adjustments occurred at only two SO₂ stations--Dekorrra and Messer--and resulted in a change not exceeding 8%.

A Comment--

It should be mentioned that the SO₂ levels recorded at the sites do not represent just the SO₂ emissions from the Columbia Generating Station, but

also SO₂ transported into the study region over long distances. This long range transport is assumed to come from large industrial metropolitan areas such as Madison, Milwaukee, and Chicago. The Dames and Moore Company has done some work in correlating high SO₂ levels with wind direction. In many instances the highest levels are associated with wind sectors other than the Columbia Generating Station. The worst cases occur when the wind is from southerly directions. This puts Madison in line for being one of the major contributors to background pollution. This is not unlikely since the University heating station is an unregulated source burning a high S content fuel. Therefore, sufficient meteorological data is required to determine the effect of the Columbia Generating Station.

DATA SET C17A2: OZONE MONITORING AT THE GENRICH SITE OF THE COLUMBIA GENERATING STATION (1976-79)

Data Summary

Investigators--

Dames and Moore, Inc., Park Ridge, Illinois, under contract with WPL.

Abstract--

This data set contains hourly average records of O₃ (µg/m³) from the Genrich site, located 8.4 km north of the Columbia Generating Station, from May 1976 to Feb. 1978.

Dates of Research--

May 1976-February 1979.

Data Form--

Computer file containing 2,046 units with one card-image/unit.

Data Format

See data set C17A1.

Quality Assurance

Objectives--

The objective of this study was to characterize the level of O₃ in the vicinity of the Columbia Generating Station in order to assess the station's environmental impact. The O₃ data were collected by Dames and Moore, Inc., under subcontract from the WPL, to meet PSC requirements.

Ozone Monitoring Site--

Ozone monitoring was carried out at the Genrich site, located 8.4 km north of the Columbia Generating Station in the Wisconsin River valley, at an elevation of 245 m above MSL (Figure 31).

Monitoring Equipment--

The Genrich site included the following monitoring equipment for SO₂ and O₃:

- (1) Philips PW 9700 SO₂ Monitor
- (2) Meloy OA-350 O₃ Analyzer
- (3) Esterline-Angus L1102S Two-channel Crossover Speed Servo II Recorder
- (4) Monitor Labs 8640 Averagers (two)

The air analyzed by the SO₂ and O₃ analyzers is taken from the same manifold, whose intake is approximately 15 ft above the surface. The Meloy OA-350 O₃ analyzer measured continuously and automatically the concentration of O₃ in ambient air by photometrically monitoring the chemiluminescence resulting from the reaction of ethylene gas with ozone. The OA 350 O₃ analyzer has built-in span calibration and thermoelectric stabilization for wide-range ambient operation. Technical specifications which are of interest:

Detection limit: 0.001 ppm

Zero Drift: ± 0.25 ppb, $\pm 0.25\%$ on 0.1 ppm scale
 ± 0.50 ppb, $\pm 0.50\%$ on 0.1 ppm scale

Precision: $\pm 21\%$

Site Checks and Calibration--

The O₃ site was checked 3 times/week by a Senior Field Technician employed on a full-time basis by Dames and Moore and based in the Portage area.

The daily site checks included routine inspection of all instruments and recorders to ensure proper operation, changing strip charts, and filling out a detailed checklist of all equipment checks.

The monitor was calibrated quarterly with an ultraviolet lamp O₃ generator which was certified in the Dames and Moore Laboratory in Park Ridge, Illinois with bubblers and neutral-buffered KI method. The monitor was calibrated on the site under the same conditions that existed during normal operation. Detailed records were kept of each calibration, including "before" and "after" readings for each instrument. A detailed field memorandum was also completed for each calibration.

Data Reduction--

Same as data set C17A1.

Adjustment of Data--

Same as data set C17A1.

DATA SET C17A3: TOTAL SUSPENDED PARTICULATES (TSP) NEAR THE COLUMBIA
GENERATING STATION (1976-79)

Data Summary

Investigators--

Dames and Moore, Inc., Park Ridge, Illinois, under contract with WPL.

Abstract--

Every 6 days from March 1976 to Feb. 1979 a 24-hr average of total suspended particulates (TSP, in $\mu\text{g}/\text{m}^3$) was taken. The data were collected at four sites located 7.1 to 15.6 km from the stack of the Columbia Generating Station. Data from March to June 1976 were collected at the Portage Cemetery, Lake George, Dekorra, and Messer sites. Since July 1976 data have been obtained from the Lake George, Dekorra, Messer and Genrich sites.

Dates of Research--

March 1976-February 1979.

Data Form--

Computer file containing 696 units with one card-image/unit.

Data Format

Same as data set C17A1.

Quality Assurance

Objectives--

The objective of the study was to characterize the level of TSP in the vicinity of the Columbia Generating Station to assess the station's environmental impact. The TSP data were collected by Dames and Moore, Inc. under subcontract from the WPL to meet WPSC requirements.

Monitoring Sites--

The high volume particulate samplers were operated at four sites: Lake George, Dekorra, Messer, and Cemetery (for a description of these sites see data set C17A1). Since the Cemetery site was located between trees and very close to the railroad, the TSP monitoring equipment from this site was transferred to the Genrich site (see data set C17A2 for a description of this site) in July 1976.

Monitoring Equipment--

TSP were measured with a General Metal Works Model GMWL-2000H High Volume Air Sampling System. The flow rate measuring device was a Pressure Transducer Recorder (Part No. GMW-105).

Site Checks and Calibration--

All monitoring sites were checked 3 times/week by a senior field technician employed on a full-time basis by Dames and Moore and based in the Portage area. The daily site checks included inspection of all instruments and recorders to insure proper operation in addition to changing high volume sampler filters. A detail checklist of all equipment checks was filled out by the meteorologist during each site visit.

High-volume particulate samplers were calibrated quarterly, or more frequently when deemed necessary due to maintenance, brush life, or other factors which may have affected the flow. The sampler was calibrated with a Model GMS-25 calibration orifice unit which had been calibrated with a positive displacement meter. The orifice differential pressures (P) and the indicator readings were recorded for each of the five load plates. Measured flow was determined from the orifice units calibration curve. These data were recorded along with any other pertinent information. The calibration curves for the high-volume filters showed substantial deviation before and after maintenance. This is considered normal because changing motor brushes during maintenance often changes the flow produced by the sampler. Reported data, however, were not affected.

Data Reduction--

Particulate filters for the high volume samplers were weighed before and after sampling by the field technician. These data were processed by a computer program to determine the average particulate concentration ($\mu\text{g}/\text{m}^3$) for the 24 hr sampling period. The program also required additional input: the initial and final flow rate for the sampler (measured by the field technician) and the mean ambient temperature during the sampling period. All TSP concentrations were corrected to Standard Temperature and Pressure (25°C and 1013 mb) in accordance with the U.S. EPA Storage and Retrieval of Aerometric Data (SAROAD) format.

Adjustment of Data--

The calibration data were input into the particulate analysis computer program which corrected the flow indicator readings to the actual flows.

DATA SET C17B1: AIR TEMPERATURE NEAR THE COLUMBIA GENERATING STATION (1976-79)

Data Summary

Investigators--

Dames and Moore, Inc., Park Ridge, Illinois, under contract with WPL.

Abstract--

This data set contains hourly-average records of air temperature (°C) measured at two sites near the Columbia Generating Station. At the Lake site, located 2.4 km south-southeast of the power plant, temperature was measured at a height of 10 m; at the Tower site, located 7.1 km west of the power plant, temperature was measured at 30 m.

Dates of Research--

March 1976-February 1979.

Data Form--

Computer file containing 4,258 units with one card-image/unit.

Data Format

Field Description--

All data sets in part C17B use the same modified Storage and Retrieval of Aeromatic Data (SAROAD) field description as follows.

<u>Column</u>	<u>Format</u>	<u>Description</u>
1-3	I3	State identifier, 151=Wisconsin
4-7	I4	Location identifier; 0600=Columbia County, 2780=City of Portage
8-10	A3	Parameter identifier (see Table 41)
11	A1	Funding agency type, J=private
12-13	I2	Project classification; 02=source-oriented ambient surveillance
14	I1	Time interval between measurements
15-16	I2	Year
17-18	I2	Month
19-20	I2	Day

21-22	I2	Hour of first measurement
32	I1	Decimal locator (columns from right)
33-80	12I4	Observation

Missing Data--

Missing data are indicated by 999.

TABLE 41. PARAMETER IDENTIFICATION CODE
AND DESCRIPTIONS FOR DATA SETS C17B1-C17B8

Data set	Code	Description	Units
17B1	TTC	Tower temp 30 m	°C
17B1	LTC	Lake temp 10 m	°C
17B2	TDC	Tower delta temp 91-30 m	°C
17B3	TS3	Tower wind speed 30 m	mph
17B3	TS9	Tower wind speed 91 m	mph
17B3	LS	Lake wind speed 10 m	mph
17B4	TD3	Tower wind direct 30 m	Degrees
17B4	ID9	Tower wind direct 91 m	Degrees
17B4	LD	Lake wind direct 10 m	Degrees
17B7	LPM	Lake atmos. pressure	Millibars
17B6	LPI	Lake precipitation	Inches
17B8	TR3	Tower net radiation	Langleys/min.
17B5	TG3	Tower vert wind direct 30 m	Degrees
17B5	TG9	Tower vert wind direct 91 m	Degrees

Data Sample

The sample presented here is 10 units, 1 to 10, of the 4,258 units included in data set C17B1.

1234567890123456789012345678901234567890123456789012345678901234567890

1510600LTCJ02176030100	1	-5	-5	-5	-22	-22	-22	-33	-33	-33	-11	-11	-11
1510600LTCJ02176030112	1	-16	-16	-16	-5	-5	-5	-5	-5	-5	0	0	0
1510600LTCJ02176030200	1	5	5	5	0	0	0	-5	-5	-5	0	0	0
1510600LTCJ02176030212	1	11	11	11	5	5	5	0	0	0	0	0	0
1510600LTCJ02176030300	1	5	5	5	0	0	0	-5	-5	-5	-5	-5	-5
1510600LTCJ02176030312	1	-5	-5	-5	-11	-11	-11	-16	-16	-16	-22	-22	-22
1510600LTCJ02176030400	1	-22	-22	-22	-27	-27	-27	-22	-22	-22	-11	-11	-11
1510600LTCJ02176030412	1	5	5	5	11	11	11	5	5	5	5	5	5
1510600LTCJ02176030500	1	5	5	5	16	16	16	-5	-5	-5	-27	-27	-27
1510600LTCJ02176030512	1	-38	-38	-38	-22	-22	-22	-38	-38	-38	-66	-66	-66

Quality Assurance

Objectives--

The goal of the study was to provide temperature measurements for understanding the patterns of atmospheric dispersion in the vicinity of the Columbia Generating Station and the structure of the transport system through which materials from the generating station were dispersed through the atmosphere.

Monitoring Sites--

Air temperature was monitored from towers located at two sites, Tower and Lake (Figure 32). The Tower site is located 7.1 km west of the Columbia Generating Station at an elevation of 390 m above MSL. The Tower site is located on top of the Baraboo Hills, near the Messer site, which is described in data set C17A1. The temperature sensor at the Tower site is located 30 m above ground. The Lake site is located 2.4 km south-southwest of the power plant at an elevation of 245 m above MSL. This site is located just south of the southern end of the cooling lake. The air temperature sensor is located 10 m above ground at this site.

Monitoring Equipment--

Each of the two air temperature monitoring sites included the following equipment:

- (1) Rosemount Series 78 Platinum Resistance Temperature Sensor; and
- (2) Esterline Angus L11025 Two-Channel Crossover Recorder.

The Rosemount sensors follow the International Resistance vs. Temperature Curve (IPTS-68) with an "Alpha" coefficient of 0.00385 ohms/ohm/°C. These sensors have a temperature range of -100° to 660°C.

Accuracy levels: $\pm 0.26^{\circ}\text{C}$ at 0°C
 $\pm 0.5^{\circ}\text{C}$ at 100°C
 $\pm 1.6^{\circ}\text{C}$ at 325°C
 $\pm 1.9^{\circ}\text{C}$ at 400°C

All calibrations are traceable to the National Bureau of Standards (NBS) and in accordance with the International Practical Temperature Scale of 1968 (IPTS-68).

Technical specifications that are of interest:

Repeatability: 0.025% of temperature, or 0.05°C , whichever is greater.
Stability: 0.2% of exposed temperature, or 0.25°C , for 1 yr of service.
Time constant: < 5.5 seconds (in water at $76 \pm 5^{\circ}\text{C}$ flowing at 3 fps).
Self heating: < 60 mW/°C (in water at $76 \pm 5^{\circ}\text{C}$ flowing at 3 fps).
Sensor pressure limit: 2,500 psig at 200°C .

The Esterline Angus Speed Servo 11 two-channel crossover recorders have a response speed faster than 0.3 sec full scale and an accuracy of $\pm 0.025\%$ of span or 3.5 microvolts whichever is greater.

Site Checks and Calibration--

Rosemount Model 414L linear bridges were used in making pre-adjustment checks, converting the resistance of the platinum resistance sensor to a millivolt/degree output signal. These linear bridges have an accuracy of $\pm 0.17\%$ of span. The absolute temperature readings from each bridge are not affected by ΔT connection.

Other required test equipment:

<u>Equipment</u>	<u>Measurement</u>	<u>Accuracy</u>	<u>Resolution</u>
DVM	Millivolts	± 0.01 mv	0.01 mv
Psychrometer	Temperature ($^{\circ}\text{C}$)	$\pm 0.5^{\circ}\text{C}$	0.2°C
A.S.T.M thermometer	Temperature ($^{\circ}\text{C}$)	$\pm 0.1^{\circ}\text{C}$	0.1°C
Voltage source	Stable to:	± 0.2 mv	0.5 mv
Temperature bath		N/A	N/A

Each probe was removed from the tower and connected to the bridge circuit. A temperature bath was prepared. After making sure the bath was well agitated, recordings were made at three temperatures: (1) ice point, (2) near 35° ; and (3) an intermediate point. Readings included bath temperature, E-out upper bridge, E-out lower bridge, amplifier E-out (mv), the readings on the analog Esterline-Angus and the digital recorder. The target reading for the recorder at the three temperatures was $0.0 \pm 0.1^{\circ}\text{C}$.

DATA SET C17B2: AIR TEMPERATURE GRADIENT AT THE TOWER SITE NEAR THE COLUMBIA GENERATING STATION (1976-79)

Data Summary

Investigators--

Dames and Moore, Inc., Park Ridge, Illinois, under contract with WPL.

Abstract--

This data set contains hourly-average records of air temperature differences ($^{\circ}\text{C}$) between a pair of measurement points located 30 m and 91 m above the ground at the Tower site. This site is located 7.1 km west of the Columbia Generating Station.

Dates of Research--

March 1976-February 1978.

Data Form--

Computer file containing 2,068 units with one card-image/unit.

Data Format

Field Description--

Same as data set C17A1.

Quality Assurance

Objectives--

This study was designed to measure the static stability of the atmosphere between a series of measurement points.

Monitoring Site--

Air temperature differences were monitored between a pair of measurement points located 30 m and 91 m above ground at the Tower site, located 7.1 km west of the Columbia Generating Station at an elevation of 390 m above MSL.

Monitoring Equipment--

Same as data set C17A1.

Site Checks and Calibration--

Same as data set C17A1.

DATA SET C17B3: WIND-SPEED MONITORING NEAR THE COLUMBIA GENERATING STATION (1976-79)

Data Summary

Investigators--

Dames and Moore, Inc., Park Ridge, Illinois, under contract with WPL.

Abstract--

This data set contains hourly-average records of wind speed (mph) measured at two sites near the Columbia Generating Station. At the Lake site, located 2.4 km south-southwest of the generating station, wind speed was measured at a height of 10 m. At the Tower site, located 7.1 km west of the generating station, wind speed was measured at two heights, 30 and 91 m.

Dates of Research--

May 1976-February 1979.

Data Form--

Computer file contained 6,152 units with one card-image/unit.

Data Format--

Same as data set C17A1.

Quality Assurance

Objectives--

The purpose of the study was to provide data for understanding the patterns of atmospheric dispersion in the vicinity of the Columbia Generating Station, providing an estimate of the speed of transport of materials from the generating station through the atmosphere.

Wind Speed Monitoring Sites--

Wind speed was monitored at two sites, Tower and Lake. The Tower site was located 7.1 km west of the Columbia Generating Station at an elevation of 390 m above MSL. The two wind speed sensors at this site were located 30 and 91 m above the ground. The Lake site was located 24 km south of the power plant at an elevation of 245 m above MSL. The single wind speed sensor at this site was located 10 m above ground.

For a discussion of site selection see data set C17A1.

The data collection and reduction and the equipment maintenance were all performed by Dames and Moore Company (consultants in environmental sciences), Park Ridge, Illinois. The equipment belonged to WPL.

Monitoring Equipment

Wind speed monitoring instrumentation at each of the three locations included:

- (1) Tech Ecology Model 01 wind speed sensor
- (2) Monitor Lab 8640 Averger
- (3) Esterline-Angus 2L102 Two-Channel Parallel Speed Servo II Recorder.

The Tech Ecology Model 01 wind speed sensor consists of a light-weight 3-cup anemometer coupled directly to a disk with slots. The disk rotates and interrupts the signal between a solid state light source and detector. The signal is amplified and provides an electrical output proportional to

the wind speed. This sensor has an operating range of 0-60 m/sec (or 0-125 mph) and an accuracy of $\pm 1\%$ or 0.15 mph.

The output signal of the sensor is accepted by the Monitor Labs Averager which outputs an analog voltage proportional to the average value of the input over a period of 1 hr.

Technical specifications:

Accuracy and linearity:

Average of 0-10% FS = $\pm 0.5\%$ FS or better

Average of 10-25% FS = $\pm 1\%$ FS or better

Average of 25-100% FS = $\pm 2\%$ FS or better

Time accuracy: synchronized to line frequency.

Stability: $\pm 0.5\%$ full scale/month.

The data were recorded on Esterline-Angus 2L102S two channel parallel-speed Servo II Recorders (described in data set C17B1)

Site Checks and Calibration--

The Tech Ecology Model 010 wind speed sensor was calibrated quarterly, or more frequently as deemed necessary.

For a description of the site checks, refer to data set C17B1.

DATA SET C17B4: HORIZONTAL WIND DIRECTION MEASUREMENTS NEAR THE COLUMBIA GENERATING STATION (1976-79)

Data Summary

Investigators--

Dames and Moore, Inc., Park Ridge, Illinois, under contract with WPL.

Abstract--

The data set contains hourly-average records of wind direction measured at two sites near the Columbia Generating Station. At the Lake site, located 2.4 km south-southwest of the generating station, wind direction was measured at the height of 10 m. At the Tower site, located 7.1 km west of the generating station, wind direction was measured at two heights, 30 m and 91 m.

Dates of Research--

May 1976-February 1979.

Data Form--

Computer file containing 6,152 units with one card-image/unit.

Data Format

Same as data set C17A1.

Quality Assurance

Objectives--

The purpose of this study was to provide data for understanding the patterns of atmospheric dispersion in the vicinity of the Columbia Generating Station. This data set documents horizontal wind direction which contributes to the estimation of the speed and direction of the transport of materials from the generating station through the atmosphere.

Monitoring Sites--

Horizontal wind direction was monitored at two sites, Lake and Tower. The Tower site was located 7.1 km west of the Columbia Generating Station at an elevation of 390 m above MSL. The horizontal wind direction sensor was located 10 m above ground. The Lake site was located 2.4 km south of the power plant at an elevation of 245 m above MSL. The air temperature sensors were located at two heights, 30 and 91 m, above ground.

Monitoring Equipment--

The horizontal wind direction monitoring equipment at each site included:

- (1) Tech Ecology Model 020 Horizontal Wind Direction Sensor;
- (2) Monitor Lab 8640 Averager; and
- (3) Esterline-Angus 2L102S Two-Channel Parallel-Speed Servo II Recorder.

The Model 020 horizontal wind vane consists of a light-weight polyurethane foam vane coupled directly to a single low torque potentiometer. The output is directly proportional to the horizontal wind direction.

Input power is 12VDC at 10 MA and output is 0.5 volts for 0-360° (or 340°).

Technical specifications which are of interest:

Azimuth	Electrical 0-356°--Mechanical 0-360°
Threshold	0.6 mph
Linearity	± 0.5 % of full scale

Accuracy	$\pm 3^\circ$
Damping ratio	0.4-0.6
Delay distance	< 3 ft

Site Checks and Calibration--

Degree wheel checks were conducted for the four points of the compass: west= $270 \pm 5^\circ$, east= $90 \pm 5^\circ$, south= $180 \pm 5^\circ$ and north= $360 \pm 5^\circ$ and the necessary adjustments were made. Following any adjustments, degree wheel checks were repeated.

The equipment used to monitor horizontal wind direction were calibrated quarterly (weather permitting).

For a description of the sites checks, refer to data set C17B1.

DATA SET C17B5: MEASUREMENTS OF VERTICAL WIND DIRECTION (1977-78)

Data Summary

Investigators--

Dames and Moore, Inc., Park Ridge, Illinois, under contract with WPL.

Abstract--

This data set contains hourly-average records of the standard deviation of vertical wind direction measured at 30 m and 91 m at the Tower site. The site is located 7.1 km west of the Columbia Generating Station.

Dates of Research--

June 1977-March 1978.

Data Form--

Computer file containing 2,432 units with one card-image/unit.

Data Format

Same as data set C17A1.

Quality Assurance

Objectives--

The purpose of the study was to document vertical wind direction which, together with the wind speed data (data set C17B3) provides an estimate of the speed and direction of the transport of materials from the generating station through the atmosphere.

Monitoring Sites--

Vertical wind direction was monitored at the Tower site, located 7.1 km west of the Columbia Generating Station at an elevation of 390 m above MSL. At the Tower site, one sensor was installed at each of two heights: 30 m and 91 m above ground.

Monitoring Equipment--

The wind direction monitoring included the following equipment for each height:

- (1) Tech Ecology Model 022 Bivane Sensor
- (2) Tech Ecology sigma printed circuit board.

The 022 wind vane is connected directly to a vertical potentiometer which provides an analog output voltage proportional to the vertical wind direction. The output from the rotating vertical potentiometer goes through a gold plated slip ring assembly to the output connector, a Tech Ecology sigma printed circuit board, which records standard deviation of vertical wind direction. This parameter was recorded on analog strip charts and averaged hourly.

Site Checks and Calibration--

Each site was checked 3 times/week by a senior local field technician and the required instrument adjustment and repairs were made.

Calibration was performed quarterly or more often as deemed necessary.

DATA SET C17B6: PRECIPITATION MONITORING NEAR THE COLUMBIA GENERATING STATION (1976-78)

Data Summary

Investigators--

Dames and Moore, Inc., Park Ridge, Illinois, under contract with WPL.

Abstract--

This data set contains hourly-average records of precipitation (inches) at the Lake site, located 2.4 km south-southwest of the Columbia Generating Station.

Dates of Research--

11 June 1976-30 April 1978.

Data Form--

Computer file containing 1,986 units with one card-image/unit.

Data Format

Same as data set C17A1.

Quality Assurance

Objectives--

The purpose of the study was to assess the possible relationship between rainfall and the ground-level concentration of material from the smoke stack.

Monitoring Site--

Precipitation was monitored at the Lake site, located 2.4 km south of the power plant at an elevation of 245 m above MSL.

Monitoring Equipment--

The precipitation monitoring equipment consisted of:

- (1) a Weather Measure P511-E Remote Recording Heated Snow Gage and
- (2) a Weather Measure Model P521-E Event Recorder.

The snow gage operates by having rain or snow drop into an inlet funnel where the snow is melted. The water drains into a precision chrome-plated tipping bucket mechanism which activates a mercury switch each time the bucket fills and tips.

Technical specifications which are of interest:

Calibration: 0.01 inch or 0.25 mm.

Accuracy: 0.5% (calibrated at 0.5 inch/hr)

The P511-E Event Recorder used with this instrument has a 6 v dc electromagnet in the recorder that is linked to the pen arm and senses a mark on the recorder chart each time it is activated by closure of the gages' mercury switch. The pen arm moves up the scale each time an event is recorded and returns to zero after each 50 events.

Site Checks--

On the P521 Event recorder, the initial open position was marked on the chart and the pen drive cam was manually reset so that the pen was at the bottom of the chart.

For the snow gage, a graduated cylinder was used to pour 800 ml of water into the bucket. After all of the water had drained into the gage, the chart reading was recorded. This was repeated twice and the results were compared to the expected reading of 2 ± 0.02 inch. If the expected reading was not within this range, the rain gage was adjusted by changing the height of the support until the bucket tipped when 8.0 ml was poured into it.

Calibrations on the precipitation gage were performed quarterly, weather permitting.

For a description of the site checks refer to data set C17B1.

DATA SET C17B7: ATMOSPHERIC PRESSURE NEAR THE COLUMBIA GENERATING STATION (1976-78)

Data Summary

Investigators--

Dames and Moore, Inc., Park Ridge, Illinois, under contract with WPL.

Abstract--

This data set contains hourly-average records of atmospheric pressure monitored at the Lake site, 2.4 km south-southwest of the Columbia Generating Station.

Dates of Research--

11 June 1976-28 February 1978.

Data Form

Computer file containing 1,986 units with one card-image/unit.

Data Format

Same as data set C17A1.

Quality Assurance

Objectives--

Atmospheric pressure was monitored in an attempt to identify the effect of this meteorological factor on the flow of pollutants from the Columbia Generating Station into the atmosphere.

Monitoring Sites--

Atmospheric pressure was monitored at the Lake site, located 2.4 km south of the power plant at an elevation of 245 m above MSL.

Monitoring Equipment--

The atmospheric pressure monitoring equipment consisted of a Weather Measure Company B211-E Microbarograph, a large 14-cell 2.5 inch diameter aneroid sensor sensitive to pressure changes of < 0.005 inch of mercury. A bimetallic strip in the lever arm provides temperature compensation. This microbarograph has 1.5 v dc clock drive 24-hr and 7-day drum rotation.

Technical specifications that are of interest:

Scales: 945 to 1,045 millibars or 27.9 to 31.0 inch of mercury
Accuracy: $\pm 0.15\%$ of range (± 0.005 inch of mercury)
Lag time: < 0.1 sec
Scale increments: 1 millibar or 0.02 inch of mercury

Site Checks and Calibration--

The atmospheric pressure system has no specific calibration procedure or forms. Periodic checks were made with the nearest weather bureau recording station as the only reference.

DATA SET C17B8: NET RADIATION MEASURED NEAR THE COLUMBIA GENERATING STATION (1976-78)

Data Summary

Investigators--

Dames and Moore, Inc., Park Ridge, Illinois, under contract with WPL.

Abstract--

This data set contains hourly-average records of net radiation (langleys/min.) measured at the Tower site, 7.1 km west of the Columbia Generating Station.

Dates of Research--

June 1977-May 1979.

Data Form--

Computer file containing 1,216 units with one card-image/unit.

Quality Assurance

Objectives--

The purpose of this study was to determine the solar radiation at the surface of the earth near the Columbia Generating Station. Since solar radiation affects the heating of the ground and the air, it influences the movement of air and the transport of pollutants through the air.

Monitoring Site--

Net radiation was monitored at the Tower site, located 7.1 km west of the power plant at an elevation of 390 m above MSL.

Monitoring Equipment--

Net radiation monitoring instrumentation included:

- (1) a Weather Measure R422 Net Radiometer and
- (2) an Esterline Angus L1101S recorder.

The radiometer is designed to measure the difference between the incoming radiation (direct solar, diffuse solar, and long-wave sky radiation) and the outgoing radiation (reflected solar and terrestrial radiation). Simultaneously measuring both incoming and outgoing radiation, the sensor provided an output signal to the recorder proportional to the sum of the outgoing radiation. The R422 Net Radiometer, equipped with an integral silica gel dehydration cylinder, has an output signal from 5.5 to 6.5 mV at 1 g-cal/cm²/min. or approximately 8 mV full scale. The radiometer has a range from 0.3-80.0 μ m covering short- and long-wave radiation. The thermopiles, made of copper constantin, are attached to black copper plates which are insulated from each other. Lupolene (special polyethylene) domes, 28 mm in diameter cover and protect the sensing elements. The silica gel, blue in color, turns red when it needs to be replaced.

Site Checks and Calibration--

Calibrations on the net radiometer were performed quarterly, weather permitting.

For a description of the site checks, refer to data set C17B1.

DATA SET C17C1: HOURLY GROSS POWER PRODUCTION OF THE COLUMBIA GENERATING STATION (1975-78)

Data Summary

Investigators--

WPL.

Abstract--

This data set contains hourly measurements of instantaneous gross power output (megawatts). The readings represent the combined generation of the two steam turbines which comprise Unit I of the Columbia Generating Station.

Dates of Research--

July 1975-February 1978.

Data Form--

Computer file containing 974 units with one card-image/unit.

Data Format

Field Description--

<u>Column</u>	<u>Format</u>	<u>Description</u>
1-2	I2	Year
3-4	I2	Month
5-6	I2	Day
7-78	24I3	24 hourly readings of gross power production (MW) beginning at 1:00 a.m.

Missing Data--

Missing data are indicated by 999. Zero gross megawatt output indicates hours during which the power plant was completely shut down.

Data Sample

The sample presented here is 10 records, 21 to 30, of the 974 records included in data set C17C1.

1234567890123456789012345678901234567890123456789012345678901234567890

75 721290256239227236246274324366367376368369369367368363366372369370360367373 1
75 722373350340330324321350369373374378379383378380378372372372375375375358371 1
75 723367370368373375369369375371370368367368369374378373375279225231257328369 1
75 724374367366346334338339364368369370365368373372373373374374355351346304303 1
75 725308291273272270281337379372368373373372373378375577374371368376371371316 1
75 7262382312272161921972172562782952993163233243233253243223223291249229209 1
75 727209210212223247249250257259256258284309318320322322326352351357372352310 1
75 728306307305302276277310363369373372371367370369372 0 0 0 0 0 0 0 0 1
75 72929826124122022222220221218238257274350368371369364356373370368367373340 1
75 73024021822222222221231331375380378373374373372372372372373373373374372371 1

Quality Assurance

Objectives--

The purpose of monitoring hourly gross megawatt load was to estimate the total amount of electrical energy (MWh) produced by the power plant during a specified period of time. The data are applicable for use in efficiency or capacity calculations. When computing efficiency, the data are compared to coal consumption data using an estimate of the BTU/lb of the coal (available Dec. 79). Percent of capacity operation is calculated by dividing any measurement by the capacity output of 527 MWH. It should be noted that these measurements in no way indicate power plant demand or the amount of electrical energy sold to consumers. This is because there are substantial uses of electricity within the power plant and also, the turbines are unable to generate < approximately 150 MW without being completely shut down.

Monitoring Equipment--

The gross megawatt output is monitored by a single General Electric Co. watt meter which measures the combined output of both turbines. The meter scale is calibrated to units of 0.1 megawatt. The manufacturer claims an accuracy of ± 0.5 megawatts.

Measuring Procedure--

The gross megawatt output was recorded hourly by a WPL employee from the watt meter. The records were written on hourly data log sheets, 1/day. The log sheets were forwarded to the main office of WPL and other interested individuals at the end of each month.

The watt meter was not routinely calibrated. However, its readings were checked daily against the sum of two similar meters installed on each steam turbine. Any watt meter found defective was replaced.

Data Recovery--

Data recovery from July 1975 through Dec. 1977 was 99.4%.

DATA SET C17C2: DAILLINOISY COAL CONSUMPTION OF THE COLUMBIA GENERATING STATION (1975-78)

Data Summary

Investigators--

WPL.

Abstract--

This data set contains daily records of the amount of coal combusted at Unit I of the Columbia Generating Station.

Dates of Research--

April 1975-March 1978.

Data Form--

Computer file containing 1,096 units with one card-image/unit.

Data Format

Field Description--

<u>Column</u>	<u>Format</u>	<u>Description</u>
1-2	I2	Year
3-4	I2	Month
5-6	I2	Day
8-13	I6	Daily coal consumption in hundreds of pounds
15-19	I5	Daily coal consumption in tons

Missing Data--

No missing data. Zero coal consumption indicates days on which the plant was shut down for repairs or biannual maintenance.

Data Sample

The sample presented here is 10 records, 208 to 217, of the 8,404 records included in data set C17C2.

```
1234567890123456789
751025  6251  312
751026  84260 4213
751027 105292 5264
751028 127659 6382
751029 138707 6935
751030 137206 6860
751031 134701 6735
751101 130459 6522
751102 126472 6323
751103 132096 6604
```

Quality Assurance

Objectives--

The objective of the monitoring was to measure the weight of coal combusted at the generating station so that daily and seasonal variations would be known along with exact dates of plant operation. This is important because the coal is the source of most of the pollutants, particulates, and thermal energy released to the atmosphere from the generating station. In addition, the coal consumption contributes to the economic cost of plant operation.

Monitoring Equipment--

The coal consumption is monitored as it is transported from the coal hopper to the pulveriser: the coal is supplied to the furnace by six coal feeders which were manufactured, already equipped with consumption monitoring devices, by the Stock Equipment Co. The monitoring equipment consists of a scale, a leveling bar remotely controlled by the scale, and a mechanical counter.

Measuring Procedure--

Coal is conveyed from the coal hopper to the two pulverizers by six parallel feeders, five of which are employed during capacity operation. Each feeder is equipped with a scale which weighs the coal occupying a specific length of belt. The weighing mechanism is attached to a leveling bar which controls the depth of coal on the belt. The leveling bar is adjusted so that the depth of coal on the belt is such that 100 lb of coal are consumed for each turn of the feeder belt's head pulley regardless of the belt speed. The action of the leveling bar is so swift that 1% accuracy of measurement is achieved.

Each pulley has its own mechanical counter in addition to an electric counter which is continuously monitored by the generating station's computer. The mechanical counters are read and recorded daily in the generating station's boiler log book where all daily data are recorded. At the end of each month the feeder records are checked against the computerized counts and totaled to give the daily consumption data presented in this data set.

SECTION 18

OUTSIDE SOURCES

This section documents data collected by sources other than the various subprojects of the Columbia impact study but which were used by one or more of the subprojects. Data were obtained from two outside sources: (1) the University of Wisconsin Arlington Experimental Farm and (2) the National Weather Service. One set of data was obtained from each of these two sources:

Data set C18A1 (Evaporation data from Arlington Experimental Farm of the University of Wisconsin-Madison) presents data that were used by the hydrogeology subproject to estimate water evaporation at the nearby cooling lake of the Columbia Generating Station. Data set C18B1 (Meteorological data obtained by the National Weather Service at Truax Field, Madison, Wis. (1973-77)) presents data that were used by the investigators of the meteorology subproject to verify and supplement the data they collected themselves.

The report was compiled by Hilary McLellan and Eric Loucks, Data Analysts, Water Resources Center.

DATA SET C18A: EVAPORATION DATA FROM ARLINGTON EXPERIMENTAL FARM 1974-76

Data Summary

Investigators--

Julian M. Martinson, Agriculture Project Supervisor, Arlington Experimental Farm.

Abstract--

This data set contains daily records from 13 June 1974 to 31 July 1976 of water evaporation in inches/day at the Arlington Experimental Farm (Figure 32). These data were used to estimate water evaporation at the cooling lake of the Columbia Generating Station.

Dates of Research--

13 June 1974-31 July 1976.

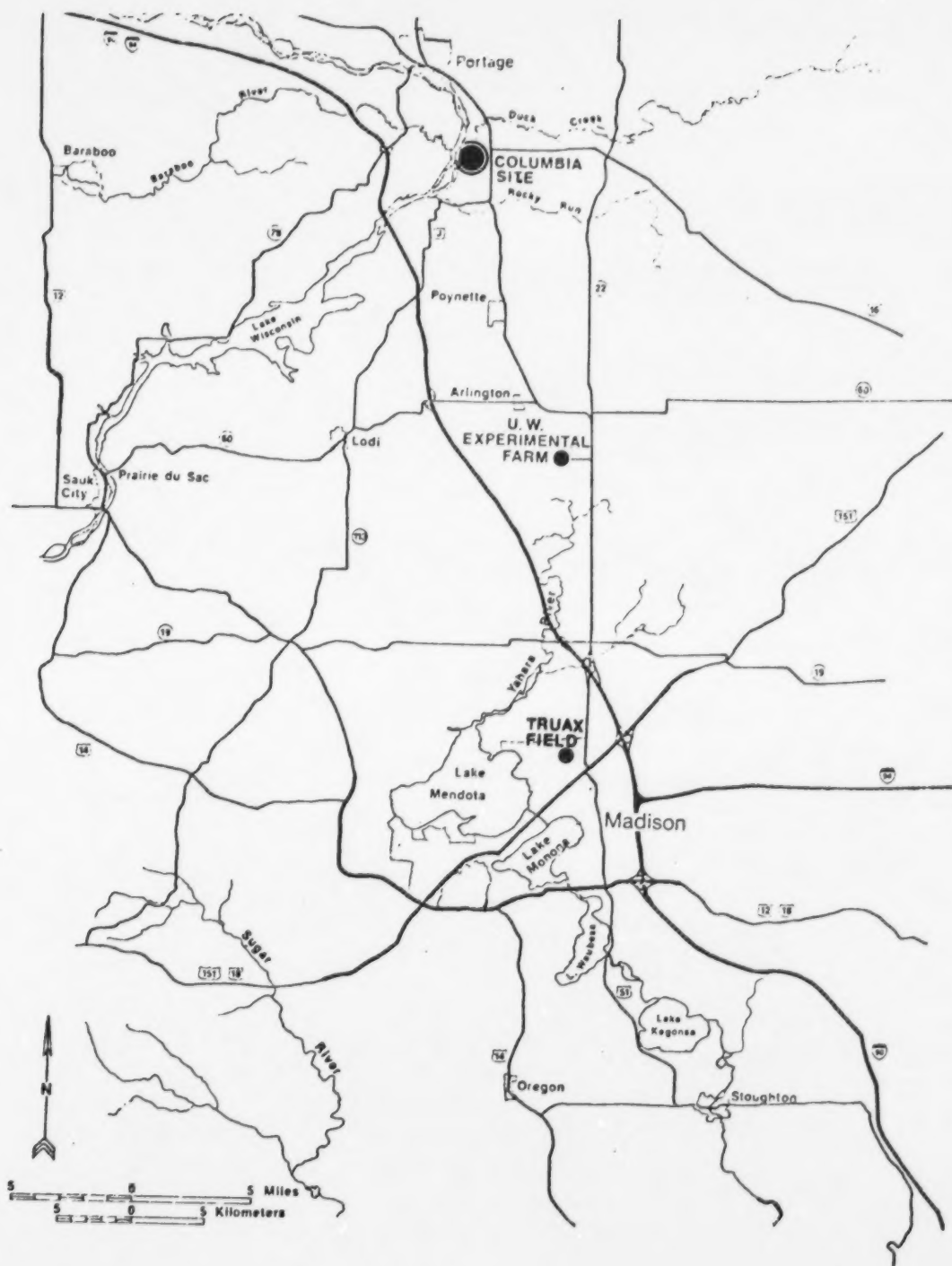


Figure 32. Map showing the monitoring sites at the Arlington Experimental Farm and Truax Field.

Data Format

Data Form--

The data are stored in 80-character card-image form on magnetic tape.
The file contains 279 units of one card-image each, with three records/card.

Field Description--

<u>Column</u>	<u>Format</u>	<u>Description</u>
1-2	I2	Month
3-4	I2	Day
5-6	I2	Year
8-12	F5.2	Evaporation/day
14-15	I2	Month
16-17	I2	Day
18-19	I2	Year
21-25	F5.2	Evaporation/day
27-28	I2	Month
29-30	I2	Day
31-32	I2	Year
34-38	F5.2	Evaporation/day

Missing Data--

Missing data are indicated by 999.

Data Sample

The sample presented here is 15 records, 1 to 15, of the 279 units in the complete data set C18A1.

123456789012345678901234567890123456789012345678901234567890

61374	.25	61474	.21	61574	.22
61674	.20	61774	.09	61874	.16
61974	.13	62074	.15	62174	.24
62274	.23	62374	.20	62474	.21
62574	.26	62674	.30	62774	.35
62874	.30	62974	.33	63074	.52
70174	.30	70274	.37	70374	.45
70474	.18	70574	.30	70674	.32
70774	.38	70874	.29	70974	.24
71074	.17	71174	.27	71274	.23
71374	.27	71474	.27	71574	.46
71674	.30	71774	.36	71874	.21
71974	.36	72074	.23	72174	.25
72274	.27	72374	.27	72474	.21
72574	.33	72674	.17	72774	.25

Quality Assurance

Objectives--

The data were obtained from the University of Wisconsin Arlington Experimental Farm by the hydrogeology subproject to determine the rates of leakage from the cooling lake. The rates were used to estimate water loss at the cooling lake due to evaporation, an estimate that was needed to model the flux of water and heat in the ground water system of the Columbia site. Evaporation at the cooling lake was assumed to be equal to 70% of the evaporation-pan reading recorded at Arlington Experimental Farm. A water surface area of 1,620 ha was used in estimating the evaporation at the cooling lake.

Monitoring site--

The Arlington Experimental Farm is located approximately 20 miles south of the Columbia Generating Station (Figure 32).

Data Collection--

Evaporation-pan data were collected daily by observation of the water level in a 4-ft diameter stainless steel tank. The tank was designed to inhibit surface waves which would distort measurements. The tank was equipped with a needle point at the center marked to indicate changes in water depth as small as 0.28 inch. The tank was installed by the U.S. Weather Bureau.

Supporting Documents

Anderson, Mary, and Charles B. Andrews. 1977. Hydrogeology. In: Documentation of environmental change related to the Columbia Electric Generating Station. Institute for Environmental Studies, Report 82, Univ. of Wisconsin-Madison. p. 83-109.

DATA SET C18B1: SURFACE WEATHER OBSERVATIONS FROM THE NATIONAL WEATHER SERVICE AT TRUAX FIELD IN MADISON, WISCONSIN (1972-78)

Data Summary

Investigators--

National Weather Service, U.S. Department of Commerce, Truax Field Office, Madison, Wis.

Abstract--

This data set contains records of hourly meteorological monitoring, known as the airways surface observations, that were conducted by the National Weather Service at Truax Field. Truax Field is located 37 miles south of the Columbia Generating Station. Data from this site may be used

to supplement meteorological data collected by the meteorology subproject and the Wisconsin Power and Light Company. Parameters in the airways surface observations include records of ceiling height, wind speed and direction, dry bulb, wet bulb, and dewpoint temperatures, sea levels and station pressure, type, sky coverage, and height of each cloud layer, type, amount, and intensity of any precipitation, and indication of the occurrence of smoke, haze, dust, or blowing snow.

Dates of Research--

1972-1978.

Data Form--

Computer file containing 61,368 records with one card image/record. One year of data contains 8,760 records.

Data Format

Field Description--

<u>Column</u>	<u>Format</u>	<u>Description</u>
1-2	I2	Year
3-4	I2	Month
5-6	I2	Day
7-8	I2	Hour of day
9-11	I3	Ceiling (height of cloud cover of 60% or greater) in 100's of feet; 999=unlimited
12-14	I3	Horizontal visibility: 000=1/16 statute miles, 002=1/8; 003=3/16; 004=1/4; 005=5/16; 006=3/8; 007=1/2; 008=5/8; 009=3/4; 010=1; 012=1-1/8; 014=1-1/4; 016=1-3/8; 017=1-1/2; 018=1-5/8; 019=1-3/4; 020=2; 024=2-1/4; 027=2-1/2; 030-950=visibility in tenths of a mile (rounded); 999=unlimited
15-16	I2	Compass point wind direction; 00=calm; 11=north; 12=NNE; 22=NE; 32=ENE; 33=east; 34=ESE; 44=SE; 54=SSE; 55=south; 66=SSW; 76=WSW; 77=west; 78=WNW; 88=NW; 18=NNW
17-19	I3	Wind speed (knots)
20-22	I3	Dry bulb (air) temperature (°F)
23-25	I3	Wet bulb temperature (°F)
26-28	I3	Dew point temperature (°F)
30-32	I3	Relative humidity (percent)
33-37	F5.1	Air pressure reduced to sea level (mb)
38-41	F4.2	Air pressure at station elevation (inches Hg)

43	A1	General sky conditions of lowest cloud layer; 0=less than 1/10 sky cover; 1=thin scattered clouds; 2=scattered clouds; 3=dark scattered clouds; 4=thin broken clouds; 5=broken clouds; 6=dark broken clouds; 7=thin overcast; 8=overcast; 9=dark overcast; - = obscuration other than clouds; blank=partial obscuration
44	A1	General sky condition of second lowest cloud layer
45	A1	Third lowest cloud layer
46	A1	Fourth lowest cloud layer
47	A1	Total sky cover in tenths of the celestial dome; - = completely overcast
48	A1	Total opaque sky cover in tenths
49	A1	Sky cover of lowest cloud layer in tenths; - = 100% cover
50	A1	Type of lowest cloud; 0=none; 1=fog; 2=stratus; 3=strato cumulus; 4=cumulus; 5=cumulonimbus; 6=alto stratus; 7=alto cumulus; 8=cirrus; 9=cirrostratus; K=stratus fractus; M=cumulus fractus; N=cumulonimbus M.; O=nimbostratus; P=altocumulus castellanus; R=cirrocumulus; - = obscuring phenomena other than clouds or fog.
51-53	A3	Height of base of lowest cloud layer in 100's of feet; 888=cirroform clouds of unknown feet; --- = no clouds (fog or obscuration only)
54-58	2A1, A3	Same as columns 49-53 except data applies to the second lowest cloud layer
59	A1	Total sky cover of the two lowest cloud layers
60-64	2A1, A3	Same as columns 49-53 except data applies to the third lowest cloud layer
65	A1	Total sky cover of the three lowest cloud layers
66-70	2A1, A3	Same as columns 49-53 except the data applies to the fourth lowest cloud layer
71	I1	Indicator of the occurrence of: 1=thunderstorm; 2=severe thunderstorm (frequent intense lightening with wind gusts exceeding 50 knots); 3=report of tornado or water spout; 5=squall (an increase of wind speed of 16 knots or more lasting for at least one minute); 0=none of the above
72	I1	Indicator of the occurrence of: 1=light rain; 2=moderate rain; 3=heavy rain; 4=light rain showers; 5=moderate rain showers; 6=heavy rain showers; 7=light freezing rain; 8=moderate freezing rain; 9=heavy freezing rain; 0=none of the above
73	I1	Indicator of the occurrence of: 4=light drizzle; 5=moderate drizzle; 6=heavy drizzle; 7=light freezing drizzle; 8=moderate freezing drizzle; 9=heavy freezing drizzle; 0=none of the above

74	11	Indicator of the occurrence of: 1=light snow; 2=moderate snow; 3=heavy snow; 4=light snow pellets; 5=moderate snow pellets; 6=heavy snow pellets; 8=ice crystals; 0=none of the above
75	11	Indicator of the occurrence of: 1=light snow showers; 2=moderate snow showers; 3=heavy snow showers; 7=light snow grains; 8=moderate snow grains; 9=heavy snow grains; 0=none
76	11	Indicator of the occurrence of: 1=light sleet (ice pellets); 2=moderate sleet; 3=heavy sleet; 5=hail; 0=none
77	11	Indicator of the occurrence of: 1=fog; 2=ice fog; 3=ground fog; 4=blowing dust; 5=blowing sand; 0=none or phenomenon did not limit visibility to less than 7 miles
78	11	Indicator of the occurrence of: 1=smoke; 2=haze; 3=smoke and haze; 4=dust; 5=blowing snow; 6=blowing spray; 0=none
79-80		Wind direction in 10's of degrees clockwise from north

Missing Data--

Missing data are indicated by blanks except in columns 48-70, which deal with sky conditions in terms of cloud layer. The data in columns 48-70 are recorded every 3 hr on the exact hour, at 0, 3, 6, 9, 12, 15, 18, and 21 hr each day. For these times, observations are recorded only if the cloud layers are present (see columns 43-46); otherwise, the data fields for the high cloud layers are blank.

Data Sample

The sample presented here is record 1 to 12 of the 61,368 records in the complete data set C18B1.

1234567890123456789012345678901234567890123456789012345678901234567890

73010127092715014101910015048815012008815013008815019008815023008815016038815014
73010227048815014101715016008815013008815017008815027008815033008815026068015027
73010327098015027108815027108815027108815028109010034101404033100401034100405034
73010427100808033101515031101215020101704013048815014048815011008815006008815001
73010527008815-01008815-03018815-05018815-04008815001018815005028815000018815-02
73010627008815-06008815-07008815-07008815-04078815006098815009108815005098815003
73010727028815000038815-02038815-04108815000108815012108815012108815010106815009
73010827098815008108015006108815005108815005108815012108815013068815007038815004
73010927008815001008815-02008815-06008815-04008815004008815007008815003008815-01
73011027008815-04008815-04008815-05008815-01018815010088815014018815010067015009
730111270975150090088150060088150C3008815006008815012008815014008815009008815007
73011227008815006008815005008815005048815008088815021108815023068815023008815021

Quality Assurance

The Truax Field data conforms to standards set for first order weather bureaus by the National Oceanographic and Atmospheric Administration. These standards are the subject of numerous reports pertaining to specific observations. Users requiring information on error bounds or measurement techniques are urged to write the Director, National Climatic Center, Federal Building, Asheville, NC 28801. Users who only need further definition of descriptive meteorological terms should write to the above and request the TDF-14 surface observations manual or contact the data center.

Supporting Documents

Local Climatological Data, U.S. Department of Commerce, National Weather Service, Truax Field, Madison, Wisconsin.